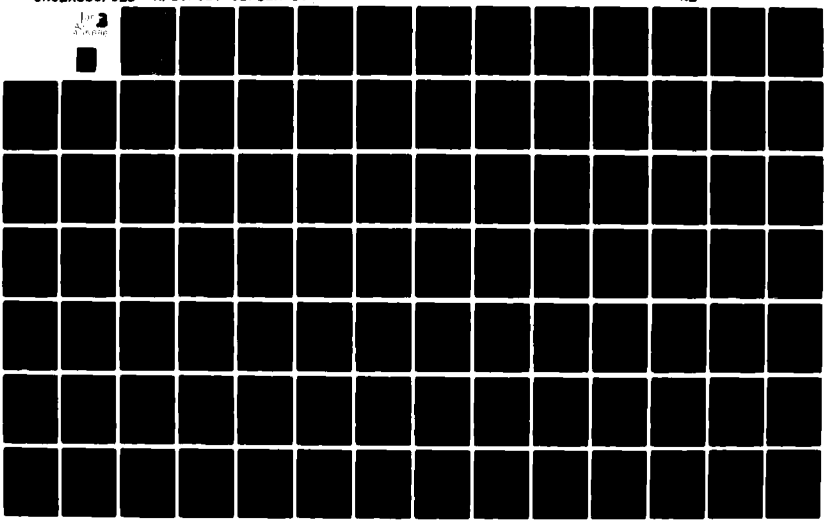
AD-A115 686 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOO--ETC F/G 5/3
A SYSTEM DYNAMICS APPROACH TO MODELING THE U.S. ARMS TRANSFER P--ETC(U)
MAR 82 M E NICKELL
UNCLASSIFIED AFIT/GST/OS/82M-10 NL



AFIT/GST/OS/82M-10

A SYSTEM DYNAMICS APPROACH TO MODELING THE U.S. ARMS TRANSFER PROCESS

THESIS

Mark E. Nickell, Captain, USAF

AFIT/GST/OS/82M-10

Approved for public release; distribution unlimited

AFIT/GST/OS/82M-10

A SYSTEM DYNAMICS APPROACH
TO MODELING THE
U.S. ARMS TRANSFER PROCESS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science

Accession For		
NTIS GRA&I		☒
DTIC TAB		☐
Unannounced		☐
Justification		
By		
Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A		

by
Mark E. Nickell, Captain, USAF
Graduate Strategic and Tactical Sciences
7 March 1982

Approved for public release; distribution unlimited

Acknowledgements

Thanks are due to many people for the inspiration, assistance, and moral support in bringing this project to completion. In particular, I would like to thank LT. Col. Thomas Clark for his advice and instruction in the area of simulation and policy analysis. Also, as a thesis advisor LT. Col. Clark was invaluable in times of indecision. A special thanks to Delores Lamont and Donna Adams for their expertise and hard work that made this thesis a professional product.

My deepest appreciation must be given to my parents Marvin and Doris Nickell for their constant support and uplifting during the final weeks of this effort when it seemed I would never finish. Their love and confidence was a major force in the completion of this thesis.

Finally, and most important, I would like to thank God for his unending love, wisdom, and guidance, for without these things I would have never been able to survive this ordeal which I will call "AFIT."

Contents

Contents

Contents

List of Figures

List of Figures

List of Figures

List of Figures

List of Tables

Abstract

The transfer of arms between countries plays a significant role in the political, economic, and military affairs of the entire world, and is, consequently, subject to constant criticism and review from many quarters. Because of the complexity of the relationships in, and the diversity of opinion about arms transfers, a concise policy which will satisfy everyone is virtually impossible to devise. This thesis is an attempt to bring together all of the significant variables concerning the arms transfer system, with particular emphasis on the welfare of United States' national interests. While this model will not be able to produce policies which will keep all interested parties satisfied, it should depict the consequences of arms transfer decisions in terms of the major variables. The model will also facilitate the examination of policies such as the dollar ceiling on sales in terms of impact on the strategic position and economy of the United States.

A Systems Dynamic Approach to Modeling the US Arms Transfer Process

I. Introduction

Background

The US Foreign Military Sales (FMS) program began in 1940 as a result of British arms purchases to fight the war in Europe. In late 1940, the British became unable to pay for additional arms which presented the US government with a considerable problem. At that time, the current Neutrability Act of 1935 only permitted arms to warring nations on a cash basis. However, in 1941, President Roosevelt stated that arms transfers to the allies of the United States would continue because it was in line with our national defense and moral obligation (Ref 6). The US entered the war in December of 1941, but continued the shipment of arms to its allies until the Japanese surrender in 1945.

After World War II, the United States European allies were unable to produce sufficient arms to defend themselves. In 1947 the US established the Military Assitance Program (MAP). Under MAP the US exported arms to selected foreign countries with no obligation for reimbursement (Ref 14). This grant aid policy was continued into the late 1960's for

countries that were considered vital to the defense of the US.

In 1961 the Kennedy administration introduced certain changes into the grant aid policy of the past. These changes suggested a new and vigorous arms transfer policy. The objectives of this new policy were to:

(1) Promote the defensive strength of our allies, consistant with our political-economic objectives,

(2) Promote the concept of cooperative logistics and standardization with our allies, and

(3) Offset the unfavorable balance of payments resulting from essential US military deployment abroad (Ref 16).

These changes resulted in a rapid growth in foreign military sales (FMS) and a redirection in the then existing militarv assistance program (MAP).

The new policy of arms sales continued into the 1970's with the full support of President's Nixon and Ford who stressed that our allies carry a greater share of the ever growing burden of Europe's defense. However, in 1976 when President Carter took office the exportation of arms to foreign countries had already mushroomed into a multi-billion dollar industry (Ref 20).

With this increase in FMS, came a growing concern over the effects it had on the rest of the world. President Carter's main concern was that:

> the virtually unrestrained spread of conventional weaponry threatens stability in every region of the world. . . Because of the threat to world peace embodied in this spiraling arms traffic; and because of the special responsibility we bear as the largest arms sellers, I believe the US must take steps to restrain its arms transfers. (Ref 3).

As a result of these concerns, President Carter in 1977 placed a ceiling on the dollar amount of FMS that could be sold to non-allied countries. Along with this ceiling came controls on advanced technology weapons sales and on sales promotions.

When President Reagan took office in 1980, a new FMS policy was put into effect. The new administration's theme was to:

> . . .Restore some sense of equalibrium in a world of growing disorder (Ref 1).

In the ensuring year under the Reagan administration, US foreign military sales have risen to over 17 billion dollars annually, which is a 15 billion dollar increase from the 18 billion dollars of FMS sold in 1970 (Ref 2). Figure 1 shows that except for 1977 and 1979 US foreign military sales have steadily increased over the last ten years.

Although the exportation of arms has risen to over 17 billion dollars annually and is controlled by Congress and the President:

> There is presently no single, formally established means for policy control of all programs for the transfer of US origin defense articles and defense services (Ref 33:44)

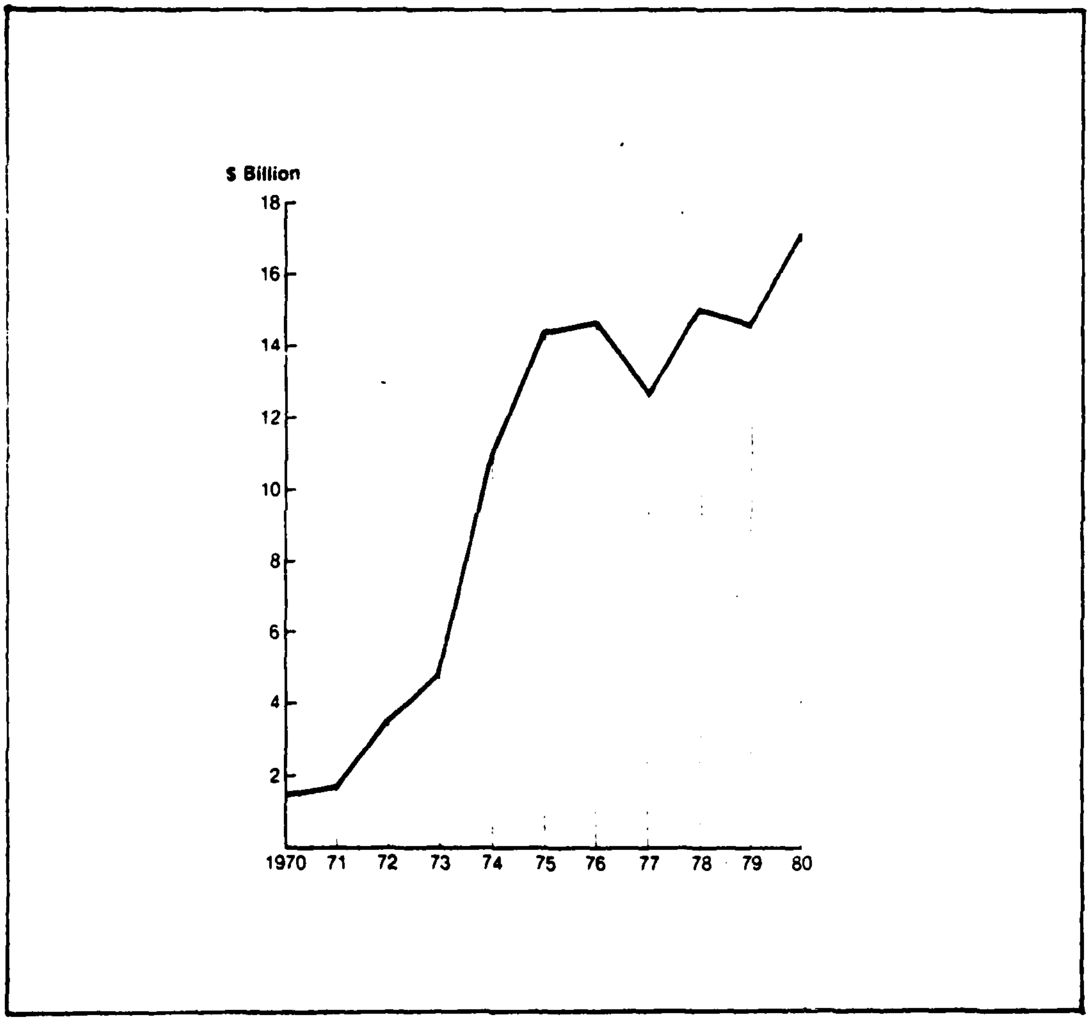


Figure 1. United States Arms Sales, 1970-1980 (Ref 11)

Those critical of arms transfers claim that:

1. There exists a lack of central controlling government agency.

2. The arms transfers create regional arms races; and instability throughout the world.

3. The sale of arms give the US a "Merchants of Death" image (Ref 24).

4. The sale of arms depletes US forces.

Those in favor of arms sales argue that:

1. Strong allies and friendly countries will reduce the likelihood of US involvement in foreign conflicts.

2. Sale of arms to foreign nations will keep production lines open (Ref 5).

3. Foreign military sales are a source of influence with customer countries.

With these opposing factors working within the government agencies a need exists for an accurate arms transfer model that could shed some light on the effects of arms transfers and related governmental policies.

Problem Statement

There exists a need to develop a dynamic model of the US arms transfer system to use as a vehicle for the analysis of the effects government policies have on foreign military sales which in turn impact upon world stability, foreign

relations and the economies of nations.

Justification for Research

There have been a number of studies and articles which have recognized the need for a better understanding of how foreign military sales influences world stability, foreign relations and the world economies. The most recent of these studies is a book published in 1982 by Andrew Pierre entitled "The Global Politics of Arms Sales (Ref 11)". In his book Pierre discusses the need for international management of arms sales. This management team would continually asses the threats to regional stability of arms sales, and review past and present arms sales to determine their effects on customer and neighboring countries (Ref 11:278-281). The major role of the management team would be to regulate exports so as to avoid arms transfers that would:

1. Create an imbalance that upsets the existing balance;
2. Start or exacerlate a local arms race;
3. Foster unstability because of the sudden acquisitions of new arms;
4. Provide incentives for a surprise attack; and
5. Provide weapons that might be used internally in a civil war, police action, or violation of human rights (Ref 11:293-294).

However, before applying these restraining policies on the transfer of arms there is a need to understand the effects that might result. To obtain this understanding, a systems analysis of the arms transfer system would be necessary.

In 1979 a research model of the US arms transfer process was developed by Chapman and Cunningham (Ref 4 which was submitted as a thesis effort for a Master's Degree. For brevity, it will be referred to as the "Arms Transfer Model".

The Arms Transfer Model was developed in an effort to better understand the effects US policy changes had on the arms transfer process. The report used a dynamic approach to modeling the FMS process. Contained in the conceptual model was several sectors; industrial, economic, government, and corresponding sectors for the rest of the world (ROW). To limit the size of the functional model the world was reduced to 32 countries by either aggregation or averaging (Ref 4). After the conceptual model was built, a computerized model was written using DYNAMO (Ref 12) a dynamic simulation language. However, because of a core limitation on the AFIT computer system and other technical problems, Chapman and Cunningham were unable to run their model to complete the verification, validation, and analysis phases of their research.

In an effort to better understand the arms transfer process and the effects they have on the world this research

effort will consider the following objectives.

Research Objectives

After briefly discussing the arms transfer process the following section will present the objectives of this research effort. The objectives of this report are:

1. Identify the structure of the arms transfer process.
   a. To define arms transfers
   b. To identify the major components that make up the arms transfer process
2. To identify the cause-and-effects feedback relationships which result from information changes by using causal-loop diagramming
3. To construct a mathematical model which encompasses the identified factors, relationships, information flows, and decision policies.
4. Verification of the functional model in sectors and as a complete entity.
5. Validation of the model by showing output behaves like the real world system.
6. To use the computer model to evaluate the effects policy changes relating to FMS have on the US economy, and world stability.

The question remains as to whether a model can measure a subjective variable such as world stability. Therefore, a research question is posed, which will be answered by the results obtained from the model.

Research Question

Using a Systems Dynamics approach to modeling (Ref 15) can the true nature of the real world arms transfer processed be captured in an effort to investigate the effects arms transfers have on regional stability. That is, do arms transfers have a de-stabilizing effect between neighboring countries?

Summary and Preview

This chapter has briefly described the nature of arms transfers and the questions of interest. The remainder of the report will be devoted to the obtainment of the listed objectives. Chapter II contains a presentation of the methodology used in this research effort. In Chapter III the model development will be discussed. Chapter IV will consider the verification of the model. The validation and analysis of model results will be discussed in Chapter V, and Chapter VI provides a brief summary of the research effort and conclusions drawn from it.

II. Methodology

Introduction

As mentioned in Chapter 1, the objective of this report is to analyze the effects of US government policy pertaining to arms transfers, on the US economy, foreign relations, and world stability. To provide the framework for this study, the System Dynamics methodology (Ref 7) was used. In accordance with the System Dynamics approach, and the first research objective of Chapter I, a hypothesized structure of the arms transfer process was constructed and is depicted in Figure 8. While the discussion of the notation used in constructing this diagram is defined, the depicted model can serve as a useful basis for discussing the appropriateness of the System Dynamics methodology.

Appropriateness of System Dynamics

The system dynamics approach to solving complex problems focusses on feedback processes. Forrester stated that systems dynamics is the

> . . . study of the information-feedback characteristics of the industrial activity to show how organizational structure, application (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise (Ref 7:13).

Therefore, this methodology allows any system of the real world or a part of it to be expressed as a feedback process.

Figure 8 depicts the relationships that exist between the variables of the arms transfer model. Implied in the arrows that connect the variables is the flow of information, money, material, capital, and orders. The levels of this flow is determined by the feedback relationships that exist within the model. As an example, if one country orders arms, then depending on the relationship that exists a neighboring country will determine if it also needs to purchase arms to negate the difference. This decision whether to purchase arms will take into account past and present information in the form of regional unstability and foreign relations. The entire arms transfer process represents an information feedback system which is the first and foremost foundation of System Dynamics (7:14). Therefore System Dynamics Methodology is used because it deals with the nature of the arms transfer process.

In using system dynamic approach to modeling, the model is designed for a specific problem and not just the general nature of the system. The modeling process is an iterative one which passes through the sequence of problem identification, model formulation, computerization, model behavior testing, reconceptualization, refinement, and policy analysis which is model usage (Ref 13:267). This process is shown in Figure 2. The following sections will be devoted to the description of how System Dynamics was applied to the arms transfer process. Also, a description of the steps

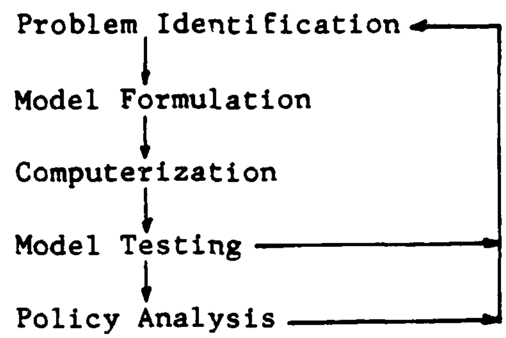


Figure 2. System Dynamics Process

involved in the System Dynamics methodology will be presented.

Problem Identification

In formulating the model, the initial task is to identify and define the problem of interest. These aspects of modeling are extremely important, because by identifying the problem one begins to raise the level of understanding about the problem. Problem identification is also important because if the wrong problem is identified for analysis the results at the end of the symulation process will not provide the required information about the problem. Therefore, problem identification consists of an exact statement of the real world problem. By specifying the goals and objectives of a problem, the problem can become well defined.

This was the purpose of Chapter I, to provide background

information about the problem, to state the specific problem of interest, and to present the objectives of the study to provide a solution path.

Model Formulation

After the problem has been defined (conceptualized), the next phase in the systems process is to develop a formal model. A formal model is basically a simplification of some slice of reality. The formal model has two advantages over the informal (mental) model on which most human decisions are based. First, formal models are tangiable which allows them to be more explicit and easier to communicate to others. This is because the nature of most mental models is to be implicit which is the cause of occassional misunderstandings (Ref 7:2-3). Second, by developing a formal model, a transistion is made from a general statement of objectives and goals to the development of exact interactions between system variables.

To accomplish this transistion, from a conceptual to a formal model, causal-loop diagramming will be used (Ref 9:5).

Causal-loop Diagramming

When investigating the nature of a dynamic process using the System Dynamics methodology, the first task is to identify the structure of the process (Ref 7:13). The tool used to initially represent this structure is the causal-loop diagram (Ref 9:5).

Causal-loop diagrams play two important roles in systems dynamics studies. First, during model development, they serve as preliminary sketches of causal hypotheses. Second, causal-loop diagrams can simplify illustrations of a model (Ref 9:5).

In both cases the causal-loop diagrams allow the modeler to quickly convey assumptions about the structure of the system. An example of a causal-loop diagram is presented in Figure 3. This diagram portrays the conceptual relationship between US Production of Arms, US Resources, US Demand to Develop Resources, US Development of Resources, and US Gross National Product (GNP).

At first glance, Figure 3 appears to have arrows going in two separate directions which would imply that a feedback relation does not exist. However, on closer examination one finds that there are two separate and complete loops contained in Figure 3. These separate loops are presented in Figures 4 and 5. If the arrows are followed through the diagram they indicate the direction in which model influence is flowing. For example, Figure 4 shows that a change in US Production and Arms will directly influence US GNP, which in turn influences US Development of Resources. US Resources directly influences two separate variables, US Production of Arms and US Demand to Develop US Resources. The final link for the loop in Figure 5 is the influence

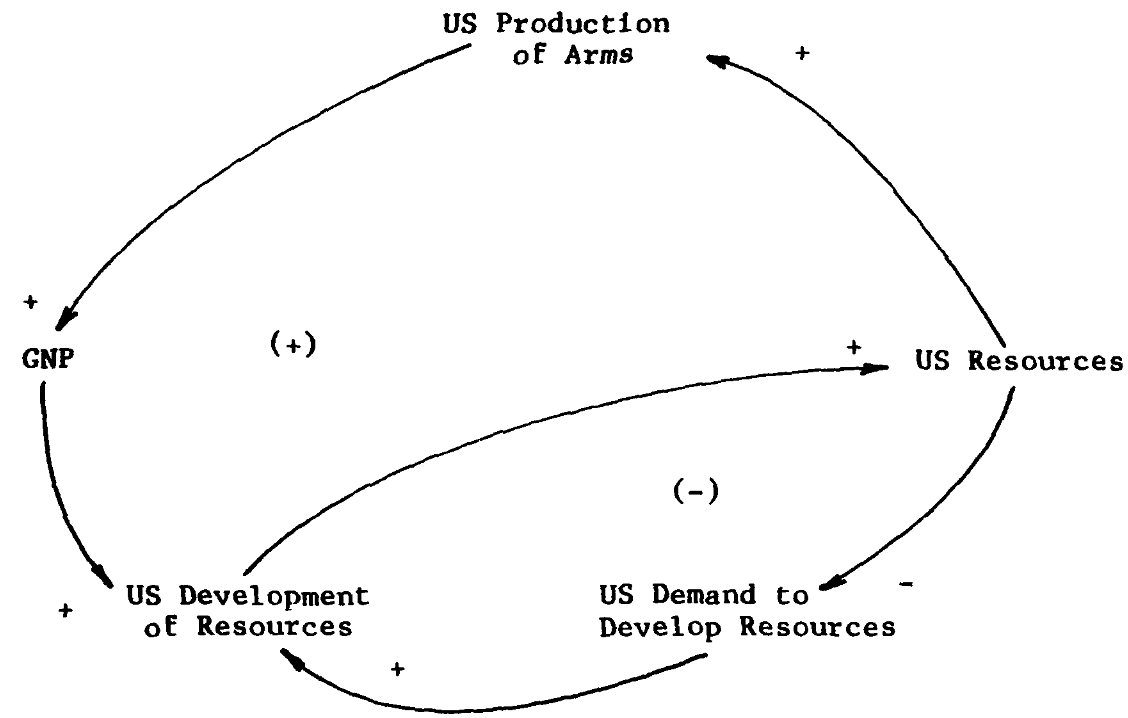


Figure 3. Example of Causal-Loop Diagram

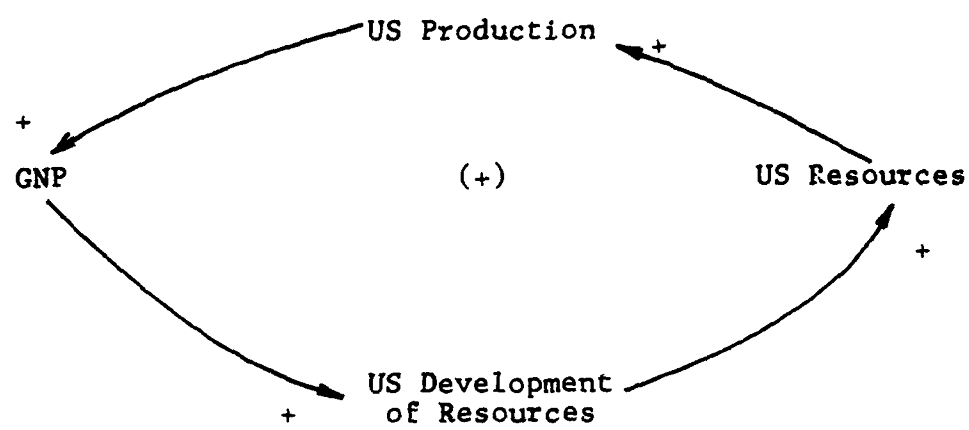


Figure 4. Positive Loop Diagram

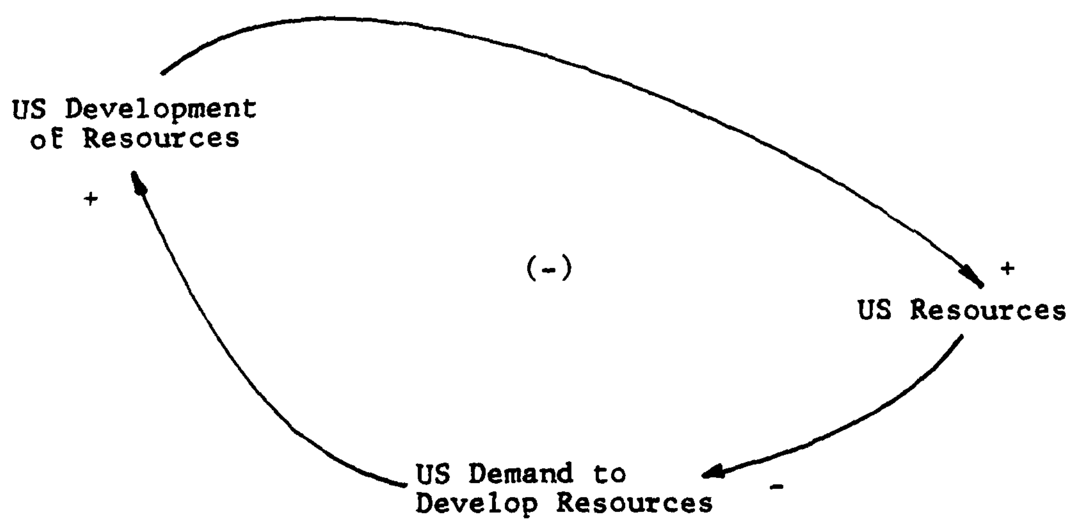


Figure 5. Negative Loop Diagram

that US Demand to Develop US Resources has on US Development of Resources.

Now that the direction of flow between the variables has been determined the next step is to indicate the nature of the influence that flows from one variable to another. This is done by observing two linked variables at a time. For example, if US Development of Resources were to increase, then US Resource would also increase. This relationship is depicted in Figure 6 where the (+) indicates a direct relationship between the two variables.

$$\text{US Development of Resources} \xrightarrow{+} \text{US Resources}$$

Figure 6. Relationship Between US Development of Resources and US Resources in Causal-Loop Format

If on the other hand an increase in one variable were to lead to a decrease in another, then an inverse relationship exists. If US Resources were to be increased, then by the laws of supply and demand, US Demand to Develop Resources would decrease as shown in Figure 7.

$$\text{US Resources} \xrightarrow{-} \text{US Demand to Develop Resources}$$

Figure 7. Relationship Between US Resources and US Demand to Develop Resources in Causal-Loop Format

Finally, the character of each closed loop causal diagram can be determined by summarizing the number of negative signs (-). If the total number of negative signs is odd then the loop is negative and is labeled as shown in Figure 4. Being a negative loop implies that the represented process will try to remain in a steady state condition. If this system is perturbed, having been in a steady state, in time the system would again reach an equilibrium state. However, if the system is positive (+) as shown in Figure 5, the system will be in a growth on decay condition.

The application of the causal-loop diagramming concept to the arms transfer process led to the development of the hypothesized relationships shown in Figure 8. While Figure 8 illustrates a combined representation, it is evident that this development of this diagram began with the construction of several individual loops of the type shown earlier in Figure 3.

Although causal-loop diagrams aid in the transition between a conceptual and formal model, they lack the precision and detail necessary in building the computer model. The causal-loop diagrams are static representations of the problem which ignore all reference to events and time. Therefore what is needed next is a method of converting the existing structural model into a dynamic one.

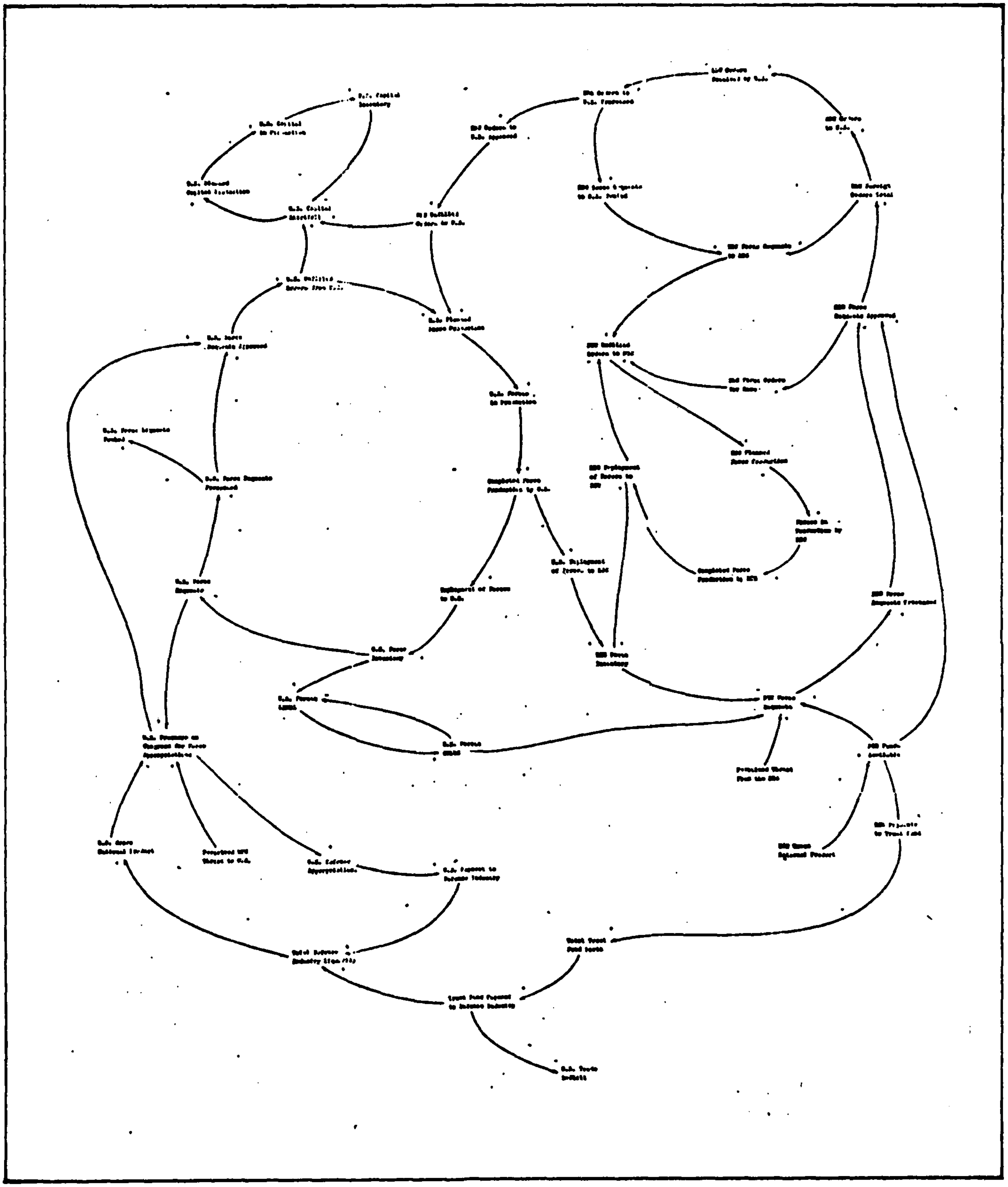
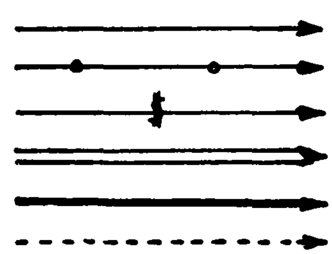


Figure 8. Causal-Loop Diagram of the Arms Transfer Process

Flow Diagramming

Flow diagramming is an intermediate step in going from the formal static model to the dynamic computer model. Flow diagrams provide the means of translating the system being modeled into a system of alternating levels and flows (Ref: 7:313). To represent the flow of material, orders/requests, money, personnel, capital equipment or information the following symbols are used:

Materials
Orders
Money
Personnel
Capital Equipment
Information

The flows shown provide a pathway for the contents of one level to flow to another. The remainder of the model is represented by a system of levels which are basically variables that represent the accumulation of material, information, or population over time. These accumulated levels are influenced by the rate at which substance flows into and out of the level. To better understand flow diagramming an example connecting the Figure 3 causal diagram will be presented. The symbology used in this example will be taken from Figure 9.

The first step in translating a causal-loop diagram into a flow diagram is to apply what is called "The Snapshot Test" (Ref:13:176-177). This test will help to identify the potential levels in Figure 3. In the test, time is considered to

Level - Measurable quantities or accumulations within the system which determine the system state

Rate - Policies that control the flows between levels

Auxiliary - Variables that provide clarification of the policy substructure of rates

Constant - Constant system parameter

Delay - Describes the process of time delays

Source/Sink - Represents levels outside the system

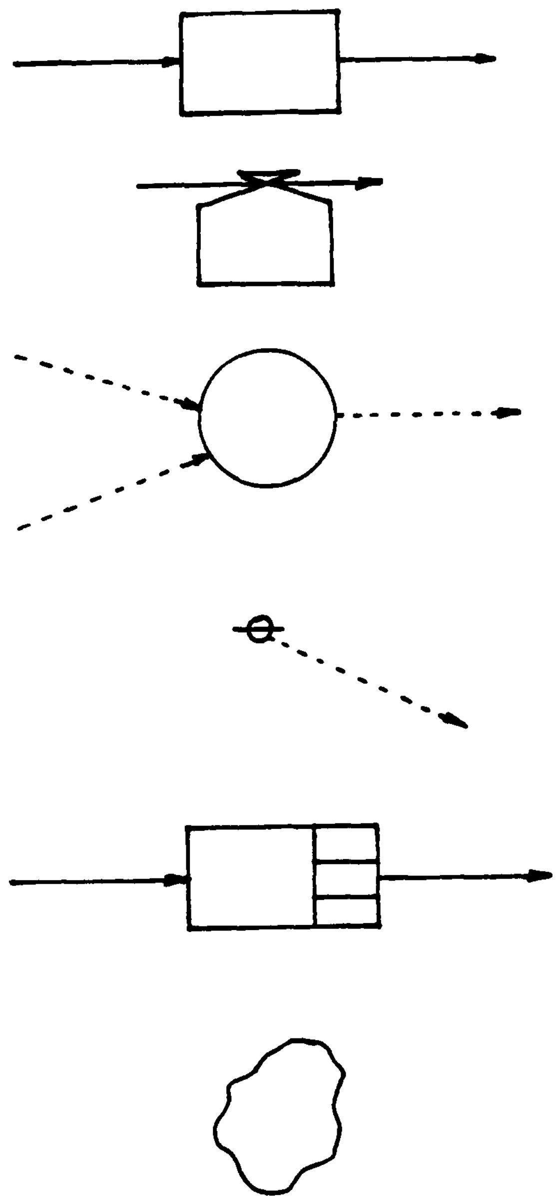


Figure 9. Flow Diagram Symbology
(Ref 7:81-84)

be instantaneously frozen and those variables which still exist and have meaning are potential levels. Looking at Figure 3, if time were instantaneously stopped only US Resources and GNP would have any meaning. The other variables, US Production of Arms, US Development of Resources, and US Demand to Develop Resources cease to exist because production, development and demand do not have meaning at a particular point in time.

Having determined the possible levels, the next step is to find those variables that have influence on US Resources and GNP. The variables influencing US Resources are US Development of Resources, US Production of Arms, and US Demand to Develop Resources. Influencing GNP are US Production of Arms, and US Development of Resources.

However, in the modeling process the modeler may be interested only with the US Resource level over time and not GNP which may effect the variable that influence US Resources. The final suggested flow diagram which results from the causal-loop diagram of Figure 3 is shown in Figure 10.

The developed flow diagram presented in Figure 10 is simple and by no means complete. However, it does illustrate how levels, flows and rates can be used to represent a feedback structure. It is also important for the modeler to realize what information is desired from the model, because this will determine the levels, rates and, auxiliaries of the flow diagram.

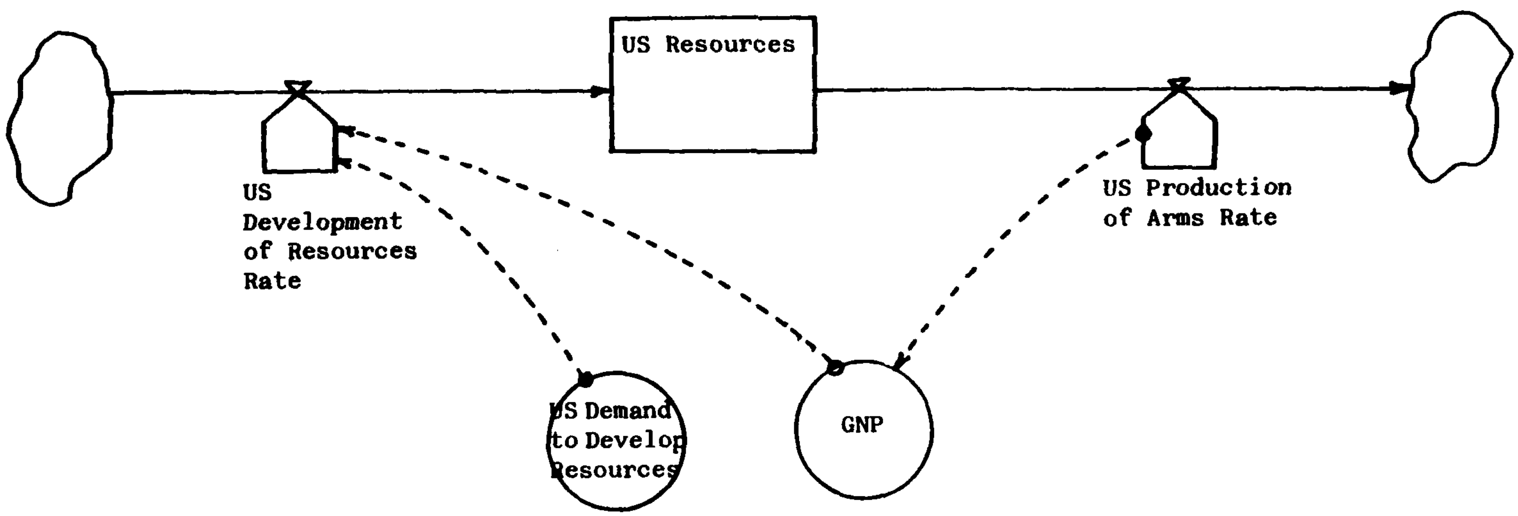


Figure 10. Example of Flow Diagram

Computerization

The next step in the modeling process is to computerize the formal model. This process of translating the formal model into one that can be simulated on a computer will be accomplished using DYNAMO (Ref 13:77-79). DYNAMO is a computer simulation language which is used to model real-world systems so that the dynamic behavior of the model can be observed.

DYNAMO used six basic types of equations to describe a system. These are the level (L), Rate (R), Auxiliary (A), Constant (C), Initialization (N) and Supplementary equations. To differentiate between past, present, and future values in the equations, the letters J,K, and L are used, respectively.

A typical example of a level equation might be written as:

INV.K = INV.J + (DT) * (PRODR.JK-SLSR.JK)

The symbols in the above equation represent specific variables where:

INV.K = current period inventory

INV.J = inventory of the last period

PRODR = production rate

SLSR = sales rate

DT = solution interval

In other words, the equation is saying that the current inventory INV.K is equal to the past inventory INV.J plus DT (time interval) times the difference between the past production rate PROD.JK and past sales rate SLSR.JK. In general, all levels will be of this form and will equal the past level plus the difference between input and output rates over a given time period (Ref 7:76).

Rate equations are used to represent the amounts of flow between levels of the system. A typical rate equation might be written as:

PRODR.KL = CONST * (DINV - INV.K)

Where:

PRODR.KL = production rate

CONST = constant production rate

DINV = desired inventory level

INV.K = current inventory level

So production PRODR.KL from this period (K) to the next period (L) equals some constant CONST times the difference between desired inventory DINV and actual current inventory INV.K.

The third, type of equation used in describing the model is called an auxiliary equation which is used as a means of simplifying rate equations. Often auxiliary equations are used when a rate equation becomes too long and complex.

An example of an auxiliary equation would be as follows:

DIFF.K = DINV - INV.K

Where:

DIFF.K = the difference between desired and actual auxiliary

DINV = desired inventory

INV.K = actual inventory

Then the above illustrated auxiliary equation would be used to simplify the rate equation introduced earlier to that shown below;

PRODR.KL = CONST * DIFF.K

In reality, the above auxiliary calculation would not be made because the rate equation was not very complex, however, it illustrates how an auxiliary might be used.

The last three types of equations, i.e., constants, initialization and supplementary equations provide additional model information. Constant equations are those which have been assigned a specific value for an entire simulation run. Initialization equations are used to set the initial values of level and table variables that will change with time. Supplementary equations can be used to establish variables which are not part of the system but can be calculated based on variables which are.

For a more detailed discussion of DYNAMO equations refer to the DYNAMO User's Manual written by PUGH (Ref 12).

After the computer model has been developed the model can be simulated in an effort to analyze and evaluate the model.

Model Behavior and Evaluation

After the model has been written in terms of DYNAMO equations the next step is to simulate the model and verify that the model is behaving as it should. For example, in the Arms Transfer Model, it is believed that an increase in US arms transfers would have a positive effect on US Balance of Trade. However, if the model doesn't react in the expected manner then the modeler will have to correct the problem. This process is also known as model verification.

An appropriate corrective action may be to first check the accuracy of the equations involved. If the equations are correct, the next step would be to insure that the flow diagrams accurately reflected the relationships identified in the causal-loop diagrams. The final step would be to go back and reconsider changing the causal-loop diagram. However, before changing the structure of the model, consider the possibility of having left an important variable out of the model.

In evaluating the model, what is actually being assessed is the validity of the model. In validating a model one attempts to show that the model accomplishes the tasks it was designed for. In validating the US Arms Transfer Model one would hope to show that the model behaved like the real

world system. The degree to which this can be accomplished will have a direct effect on the confidence one has in using the models results to make inferences about the real system.

In order to validate the US Arms Transfer Model initial values were needed for all levels in the model. Those variables for which no data existed had to be estimated based on the modelers knowledge of the real world system. Once these initial values are input into the model, the model can be simulated and the results compared to actual data. The degree to which the model's results match reality will determine the amount of corrective action that must be taken.

If the model results do not match those of perceived reality several corrective actions can be taken. The first step would be to recheck the input data to make sure it is accurate. If the inputs are accurate, then there would appear to be a problem with the model conceptualization.

Policy Analysis

Policy analysis involves the use of the model to help investigate why particular policies affect a system as they do. The model can also be used to determine what policies to enact in order to obtain some desired effect on the system.

Policy analysis can be realized by manipulating parameters within the model or by changing the structure of the model. Both of these involve changing the way decisions are

made. Such analysis is designed to increase understanding of the effects arms transfers have on the United States economy, balance of trade and foreign relations. Also by adjusting specific variables, an idea of how US arms transfers effect world stability may be studied. Definitive results, of course, are obtainable only with a truely valid model.

Policy models are difficult to validate because despite several attempts, there still is no "accepted" general methodology for validation. As Naylor and Finger (Ref 10) reported in 1967, "Despite the scope of publication and discussion, validation is still thought to be the most elusive of all the unresolved methodological problems in the social sciences."

Even though there is no accepted method of validating a policy model, there are more fundamental problems that exist. These problems include the introducing of policy decisions into a model, obtaining initial values for the model, attempting to get the model to behave like the real world, and obtaining an exact solution as in an analytical approach to the problem. Policy models are generally designed to amplify a decision makers judgement and intuition rather than produce specific answers.

Summary

The process of Systems Dynamics starts and ends with an understanding of a system and its problems. It is this understanding of the system that allows the analyst to make accurate statements about the effects policies will have on the real world process.

III. Model Formulation

Introduction

Chapters I and II provide the initial looks at the US arms transfer process and its effects on the US and ROW economies, balance of trade, and GNP. Also discussed were the effects foreign military sales have on world stability. With this information in mind it is now possible to conceptualize the US arms transfer process in terms of causal relationships which were discussed in Chapter II. Based on the available information concerning arms transfers and the objectives listed in Chapter I, the total causal diagram shown in Figure 8, was developed. Because of the size of the causal diagram and its complex interactions, the causal structure was divided into thirteen sectors for ease of discussion.

The following sections of this chapter present and discuss the thirteen sectors which makes up the US Arms Transfer Model. These sectors include the: US Force Requests Sector, US Force Requests Processing Sector, US Pressure on Congress for Force Appropriations Sector, US Force Production Sector, US Overseas Force Deployment Sector, US Capital Production Sector, US Overseas Force Deployment Sector, US Capital Production Sector, US Defense Industry Liquidity Sector, ROW Force Requests Processing Sector, ROW Orders to the US Processing Sector, ROW Funds Available Sector, and the US Employment, Gross National Product, and Balance of Trade Sector.

In addition, the causal-loop diagrams and their importance, will be discussed, to point out that although the causal structures presented in this chapter appear to be intuitive and at times very simple, one must remember that these causal structures will be combined to form the model. Once combined the true complexity of the problem will emerge. Without having first studied what would happen between variables within sectors, one will never be able to describe the intra-relationships between the variables in the model.

US Force Requests Sector

The first sector to be discussed is the US Force Requests Sector which is shown in Figure 11. US force requests are a function of several model variables which include perceived ROW threat to the US, US force inventory, ROW force inventory, and US unfilled orders. Perceived ROW threat against the United States is basically a political variable that evaluates the relationship that exists between the US and other countries of the world. As shown in Figure 11, how the US perceives the threat from a ROW country will determine the level of arms that will be "supported." If the US perceives there to be an increase in the ROW threat then there will be an increase in the number of forces the US will request to offset the difference. An example would be the large Soviet threat which is perceived by the US. Based on this threat the US attempts to adjust its force requests to maintain parity with the Soviet Union.

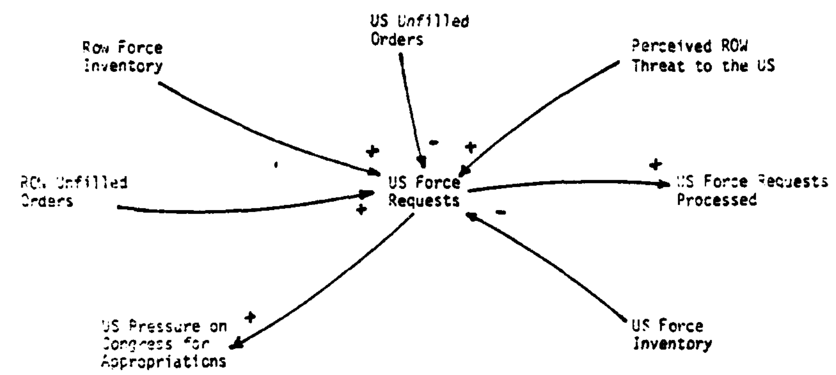


Figure 11. US Force Requests Sector---Causal Loop Diagram

Based on the perceived ROW threat the US determines the actual number of required force requests by considering the force size of the largest hostile ROW force. Then by determining the US force size which is the current force inventory plus those arms on order, a difference is obtained. From this difference a decision is made about the amount of forces the US will request. This relationship is suggested in Figure 11 by the positive flows to US force requests from the ROW force inventory and unfilled orders, and the negative flows from US unfilled orders and current US force inventory.

Based on the influences shown in Figure 11, US Force Requests has a positive influence on the number of US Force

Requests Processed and adds pressure on Congress to appropriate more funds for arms purchases. The next sector to be discussed will be the processing of US force requests.

US Force Requests Processing Sector

The US Force Requests Processing Sector is shown in Figure 12. Starting with the US force requests which was discussed in the previous sector, the figure shows that as US force requests increase, it results in an increase in the number of US force requests that are processed. Once processed, these force requests have been either approved or denied. If a request is denied it immediately becomes a forgotten request as far as the US Arms Transfer Model is

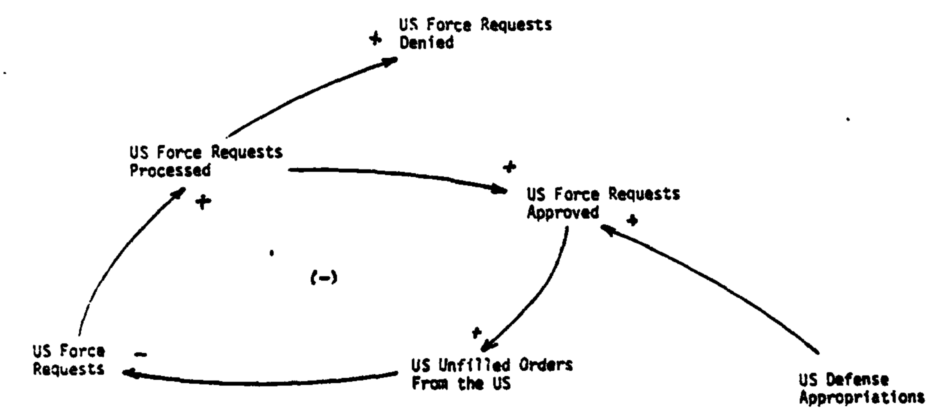


Figure 12. US Force Requests Processing Sector--- Causal Loop Diagram

concerned. In reality, those requests that are denied usually resurface under another program or at a later point in time. Those orders that are approved become unfilled orders for US industry to fill. It is important to see that the number of US forces requests that are approved are directly affected by US Defense Appropriations. This is a very necessary restriction, because without it US unfilled force requests would grow expotentially. Once the orders have been filled, the number of US Force Requests decreases as shown in Figure 12. By summing up the number of negative flows in the ordering process it appears that the causal-diagram has a negative result. This implies that this portion of the causal structure will attempt to reach a steady state condition. By being in steady state, the systems will remain unchanged until it is influenced by an outside force. If this had been a positive loop, an exponential growth situation would exist implying that force requests would be given at an ever increasing rate.

After discussing the US Force Requests process the next sector that will be discussed is the US Pressure on Congress for Force Appropriations. This is an important sector because it directly determines the level of US defense Appropriations.

US Pressure on Congress for Force Appropriations Sector

When isolated, the US Pressure on Congress for Force Appropriations Sector appears as shown in Figure 13.

Included in this causal diagram are those variables that interact to determine the amount of funds that will be made available for defense appropriations. Those variables include the perceived ROW Threat Towards the US by the ROW, the ROW Force Force Requests, US Force Requests, US Unfilled Orders, US Force Inventory, and the US Gross National Product.

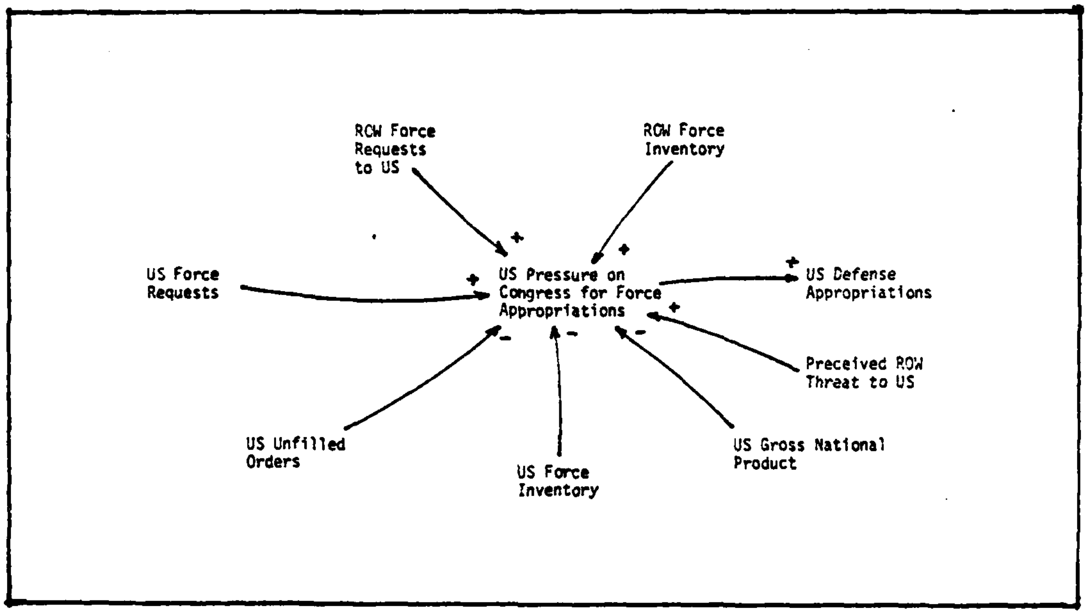


Figure 13. US Pressure on Congress for Force Appropriations Sector---Causal Loop Diagram

The sector was named US Pressure on Congress for Force Appropriations because Congress decides the amount of funds that will be made available for defense spending. From Figure 13 it is observed that US Force Requests, ROW Force

Requests, ROW Force Inventory and ROW Perceived Threat towards the US all have a positive influence on Congress. That is, as these variables increase the pressure on Congress for additional defense funds will increase. Those variables that have a negative influence on Congress are US Gross National Product, US Unfilled Orders, and the US Force Inventory. Therefore, as these values increase the pressure on Congress for more defense spending will decrease.

What ever the influence each variable has in the decision making process will determine the level of US defense appropriations. The next section will discuss the US Force production sector.

US Force Production Sector

The US Force Production Sector, when isolated from the total process depicted in Figure 8, appears as shown in Figure 14. Recalling the discussion on causal-loop diagramming from Chapter II, the interaction between the variables is apparent. Figure 14 shows that US planned force production is influenced by three system variables, US Unfilled Orders which are generated by US Force Requests, US Unfilled Orders which are those orders from the Rest of the World and the US Production Capacity. In the model the values for US Unfilled Orders from the US and ROW are dynamic in that they change with time, however, the production capacity of the US is considered to be constant and is also an upper bound on

the maximum amount of arms that the US can produce. This assumption of having a fixed upper limit on US production capacity does not limit the dynamic model because in the short run capital production can not change significantly. From the flows entering US planned force production, it is evident that as unfilled orders or production capacity increase so will planned force production.

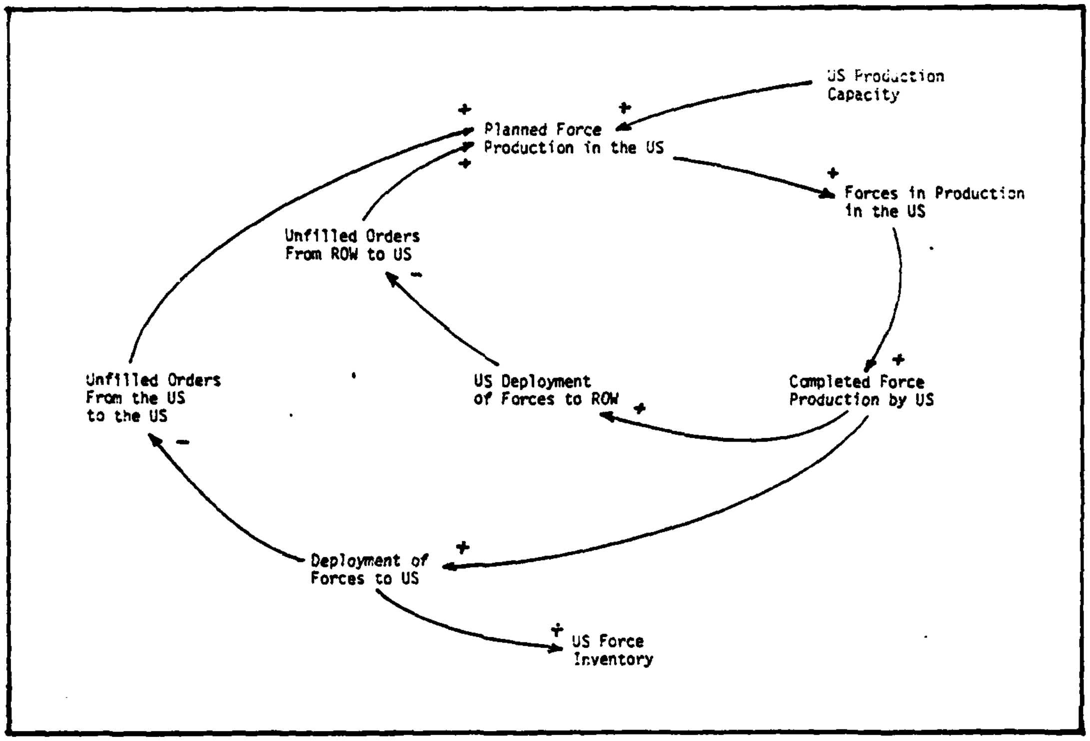


Figure 14. US Force Production Sector---
Causal Loop Diagram

As planned force production in the US increases there will also be an increase in the number of forces that will actually be in production. The forces in production

represented in this causal diagram show not only US arms production but also those arms that will be exported to ordering countries.

As the number of forces in production in the US increases there will be a corresponding increase in the number of completed forces. It is at this point in time that the forces produced in the US become divided into "ours" and "theirs" weapons systems. This division is shown in Figure 14 by the positive flows from completed force production in the US to the deployment of forces to the US and the ROW, which when received, will positively influence their respective force levels.

To complete the causal-loop, as arms are completed and deployed to the US and ROW the number of unfilled orders decreases by this total amount. This negative relationship is shown by the negative flows from US and ROW deployment of arms to US and ROW unfilled orders to the US respectively.

In looking at the Figure 14 diagram, it is obvious that there are two separate causal-loops. These causal-loop diagrams are shown in Figures 15 and 16. By adding up the number of negative flows in each diagram one finds that both causal-loop structures have goal seeking mechanisms built into them. Discussed in the next sector will be the Deployment of US Forces Overseas.

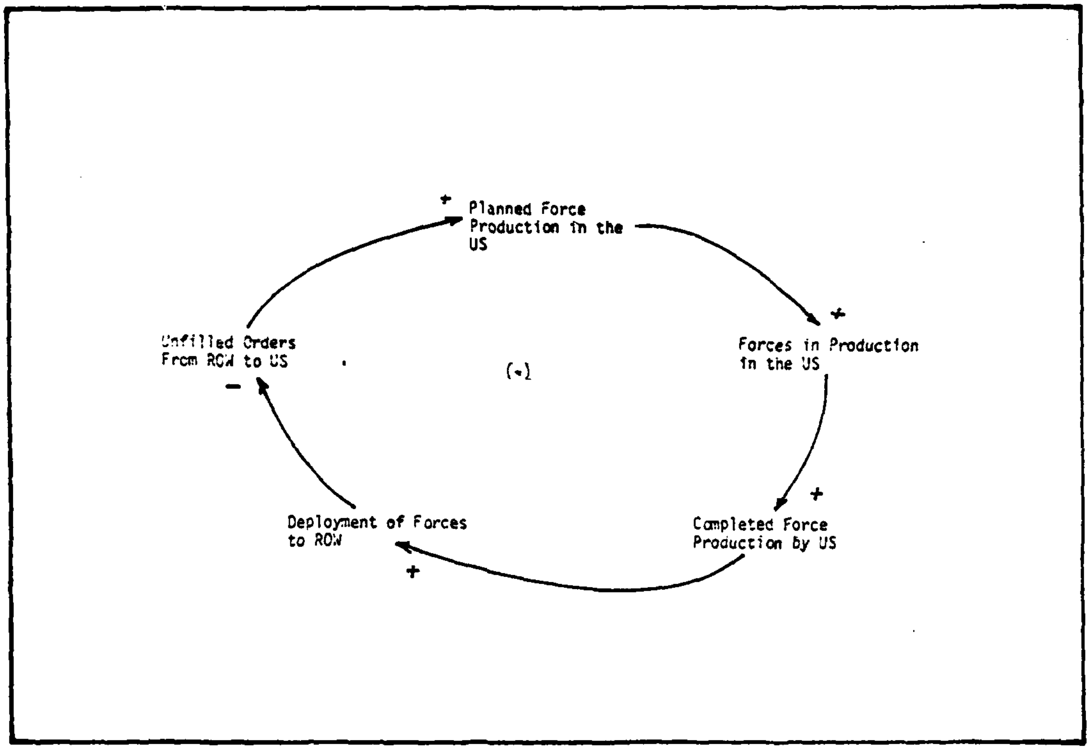


Figure 15. US Force Production Sector (I)---
Causal Loop Diagram

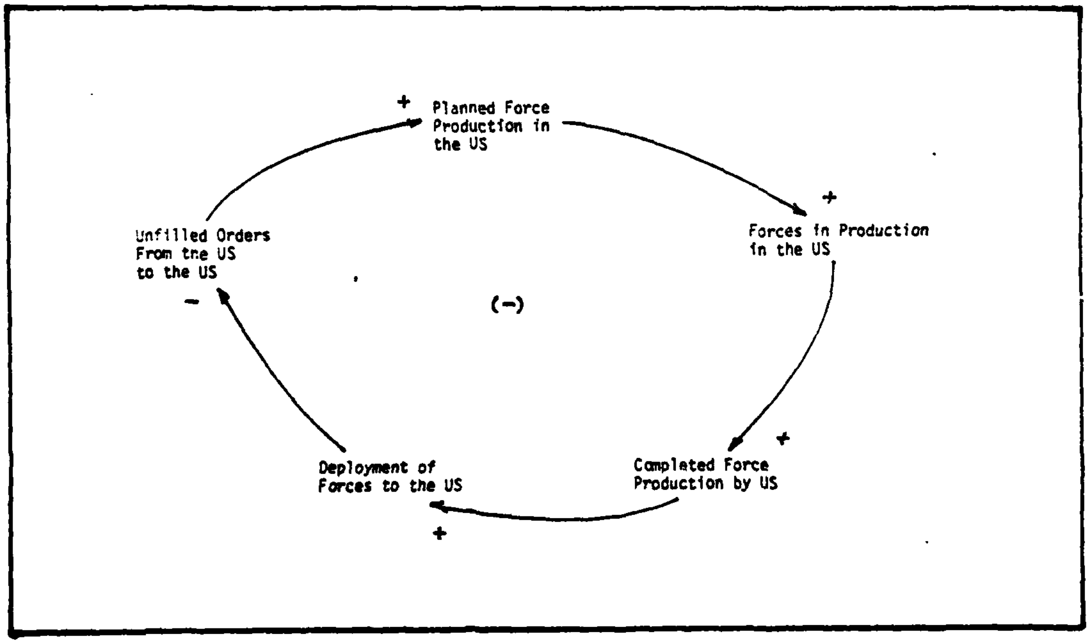


Figure 16. US Force Reduction Sector (II)---
Causal Loop Diagram

US Overseas Force Deployment Sector

When isolated from the total causal structure shown in Figure 8, the US Overseas Force Deployment Sector can be represented as shown in Figure 17. At first glance, Figure 17 seems to suggest a very straight forward relationship between US forces in the continental United States (CONUS) and the US forces stationed overseas. However, this causal-relationship represents a multitude of economic and political actions which effect both the US and rest of the world.

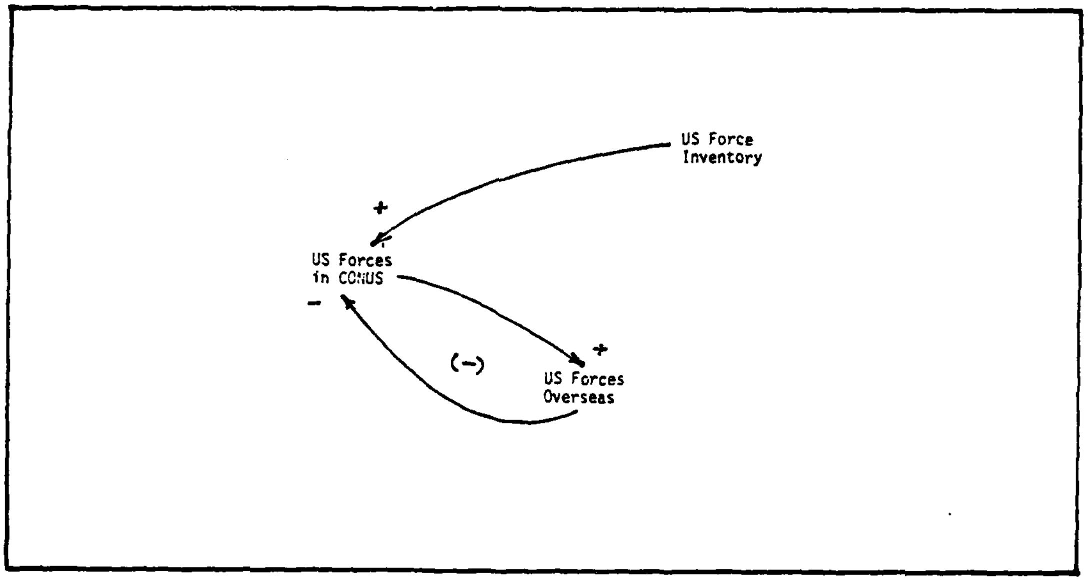


Figure 17. US Overseas Force Deployment Sector---
Causal Loop Diagram

The first of the effects Figure 17 suggests is the economic burden on maintaining US forces overseas. In 1982, the cost of maintaining US forces overseas rose to over 20 billion dollars which is one factor in the large US trade

deficit. Also because of the tremendous cost of maintaining US forces overseas there exists a limit, based on economics, to the number of forces the US is willing to maintain overseas. Another effect US forces overseas has is to influence the ROW force requests. Those countries who have US troops stationed in their countries may select not to build up their forces and allow the US to carry the burden of defense. On the other hand, US forces are only deployed in those areas where there exists a high degree of perceived threat from a neighboring country. Therefore, when the US stations troops in a country, their neighbors will perceive a greater threat and will attempt to purchase or produce more arms to effect a balance or an advantage. The final advantage which is implied by the causal relationship in Figure 17 is that by stationing US forces overseas the recipient country knows the US is committed to their defense. These economics and political effects will become more explicit in Chapter IV when the equations of the system are developed.

To complete the causal structure the ability to recall forces from overseas is included. This allows for the reduction of US overseas force levels or even a complete withdrawal, such as in Vietnam. As with the US Force Production Sector, the US Overseas Force Deployment Sector is a negative feedback loop that attempts to reach a steady state condition through the interactions hypothesized. Discussed in the next sector will be US capital, which determines US production capacity shown in Figure 14.

US Capital Production Sector

The US Capital Production Sector is shown in Figure 18. The process presented in this figure is used in determining the capacity at which the US defense industry can produce arms for the US and the ROW. Based on profits from the sales of arms to the US and the ROW, the US defense industries will plan on producing or purchasing a specific amount of capital where capital represents those materials necessary to produce arms. As the US defense industries purchase more and more capital the amount of capital in production will increase resulting in an increase in total US capital inventory. However, when the US defense industry plans on a specific amount of capital necessary for new unfilled orders, it must take into consideration the amount of capital shortfall that currently exists. That is, what amount of future capital must be used to complete past or backlog orders of weapons systems. Therefore, as the US capital shortfall increases US planned capital production will also increase.

As mentioned earlier the main objective of the sector is to determine the US production capacity which considers the capital that is available to produce arms. Discussed in the next sector will be those variables that influence and determine the level of US defense industry liquidity.

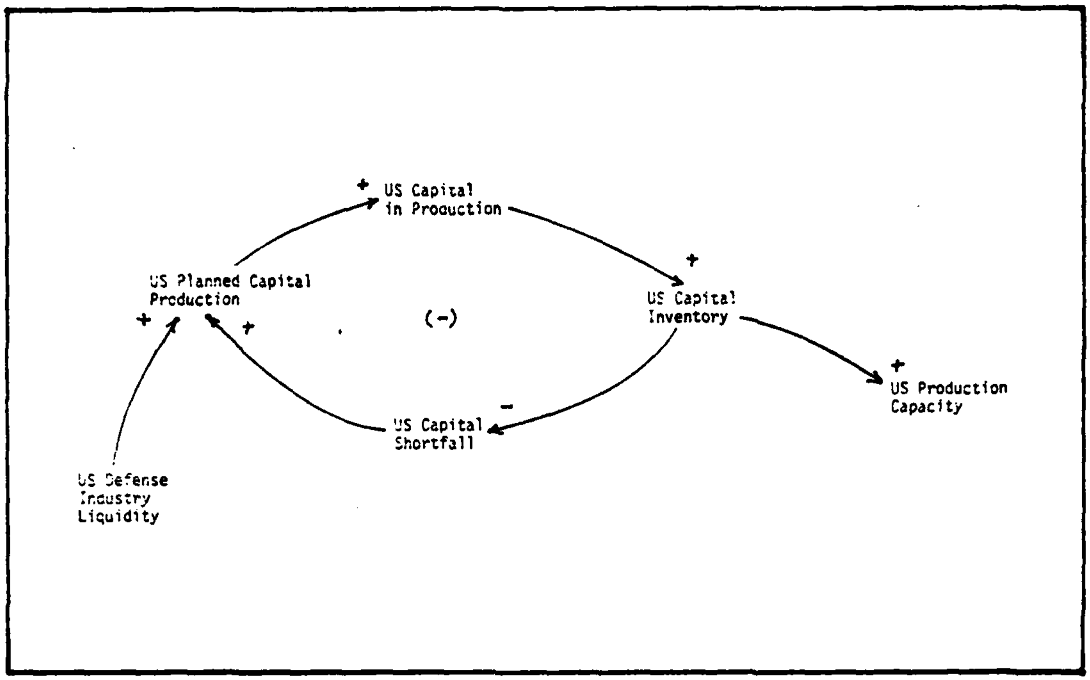


Figure 18. US Capital Production Sector---
Causal Loop Diagram

US Defense Industry Liquidity Sector

As shown in Figure 19, the US Defense Industry Liquidity Sector, is concerned with the payment of funds to the US defense industry. These funds come from two sources, the trust fund which contains payments from the ROW to the US for purchased arms and the payment of funds from the US government. From the figure it can be seen that all the flows in this sector are positive which will result in an exponential growth of US Defense Industry Liquidity. However, this will not happen because ROW payments to the Trust Fund and US Defense Appropriations are restrained within the model.

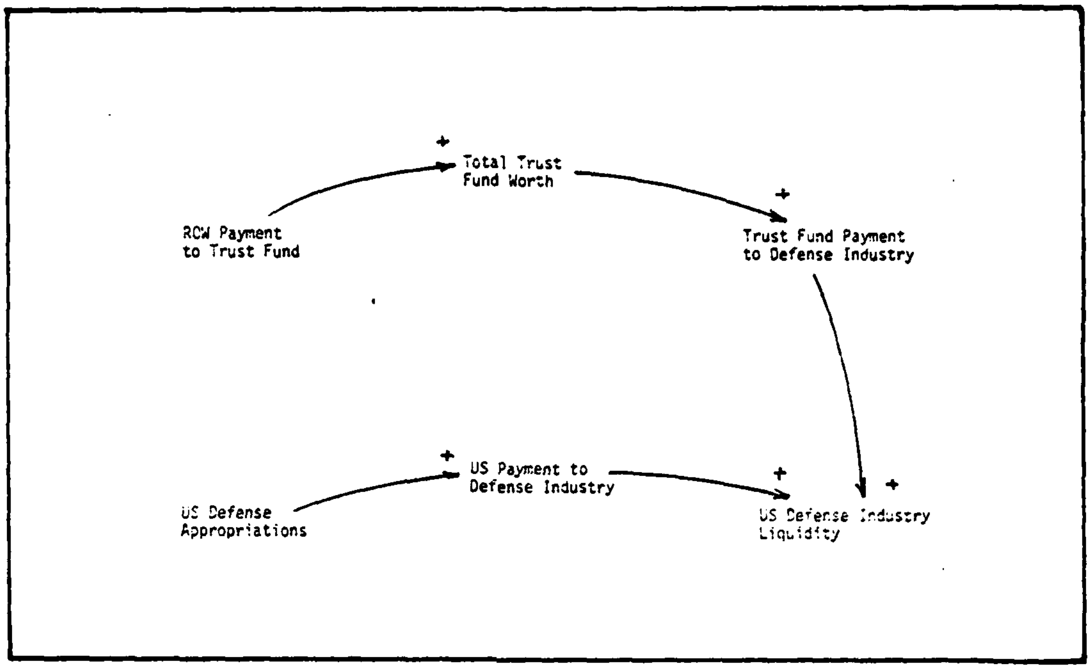


Figure 19. US Defense Industry Liquidity Sector---
Causal Loop Diagram

Now that the US portion of the arms transfer model has been presented, the discussion of the remaining sections will correspond to ROW sectors. The first ROW sector to be presented will be the ROW Force Production Sector.

ROW Force Production Sector

Figure 20 depicts the Rest of the World Force Production Sector when it has been isolated from Figure 8 . ROW planned force production is influenced by two elements in the model, ROW unfilled orders from the ROW and the ROW production capacity. As ROW planned force production increases this results in an increase in the number of total forces in production. As forces in production by the ROW increases this will

result in an increase in the number of forces that are completed. Once the forces have been completed they are delivered to their prospective buyers which incorporate them into the active inventories. This deployment of forces has two effects shown in Figure 20. The first is to increase the force size of the ROW force inventory and the other is to decrease the number of unfilled orders which are held by the rest of the world.

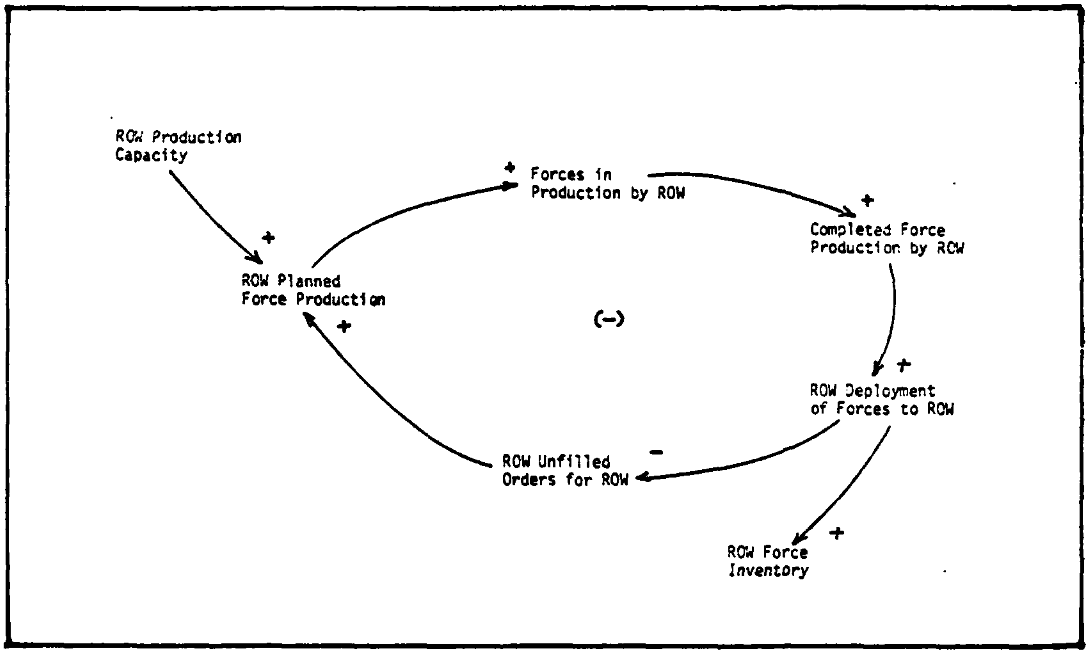


Figure 20. Rest of the World Production Sector---Causal Loop Diagram

Even though only one causal-loop diagram is shown in Figure 20 it is important to understand that this diagram represents the production process of every country in the model except the US. A complete representation of this

causal-structure in the arms transfer model would therefore consist of 18 figures identifical to that shown in Figure 20 with each representing a specific country. By summing up the number of negative flows in this causal-diagram one finds that this sector has a negative feedback structure which suggests that the ROW production process will attempt to reach an equilibrium state. Having addressed the ROW production process the next sector discussed will be concerned with the ROW foreign orders.

ROW Force Requests Sector

The ROW Force Requests Sector, in Figure 21, is a very important sector because it drives the force ordering process for the rest of the world. Because of the multitude of factors that must be considered the process of determining the ROW force requests is a highly subjective and political process. These considerations consist of, the perceived threat from a neighboring country, general stability of the region, the size of the country's existing force, what force requests made in the past remain unfilled, and the size of US forces stationed within the country.

From Figure 21, it can be seen that the variables mentioned above have both positive and negative effects on ROW Force Requests. Perceived threat is a very difficult variable to quantify, however, it plays a very important

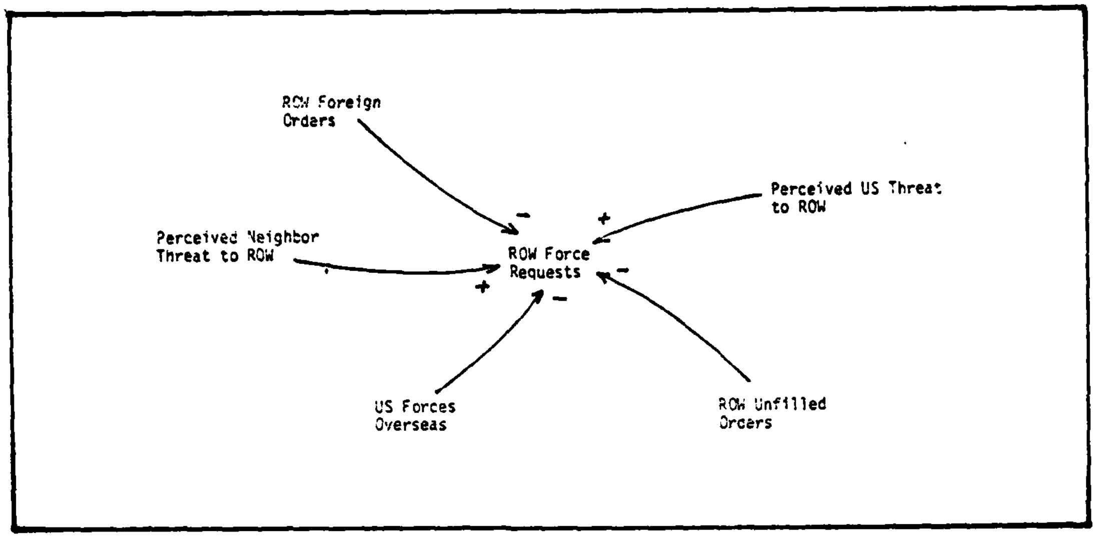


Figure 21. Rest of the World Force Requests Sector---
Causal Loop Diagram

role in determining desired or required force levels within a country. An example is how a country perceives a high level of threat possibly West Germany. Here one would feel safe to say that Germany feels very threatened by the Warsaw Pact countries, but perceives very little threat from other NATO countries. Several other variables which effect the ROW force requests are concerned with the actual size of forces within a country. The number of forces a country will request, therefore would be some perceived threat times the force level of a hostile neighboring country minus the sum of the present force level plus those arms which are on order. If there are US forces stationed in a country, then a ROW force request will decrease as shown by the negative flow in Figure 21. In the next sector the ROW Force Requests Sector will be expanded to include the ROW ordering process.

ROW Force Requests Processing Sector

When isolated, the ROW Force Requests Processing Sector is as shown in Figure 22. Starting from the ROW Force Requests which were discussed in the previous sector, the figure shows that as the ROW force requests increase, a corresponding increase in the number of ROW force requests processed will result. However, at this point the orders are either approved or denied. These approved and denied orders are determined by considering two factors, the current force inventory and available funds to purchase new arms. The orders that are denied exit the system and will no longer effect the systems process. The orders that are approved become divided into two types, those which will be filled at home and the remaining which will be filled by foreign arms manufacturers. The flows which complete the causal-structure

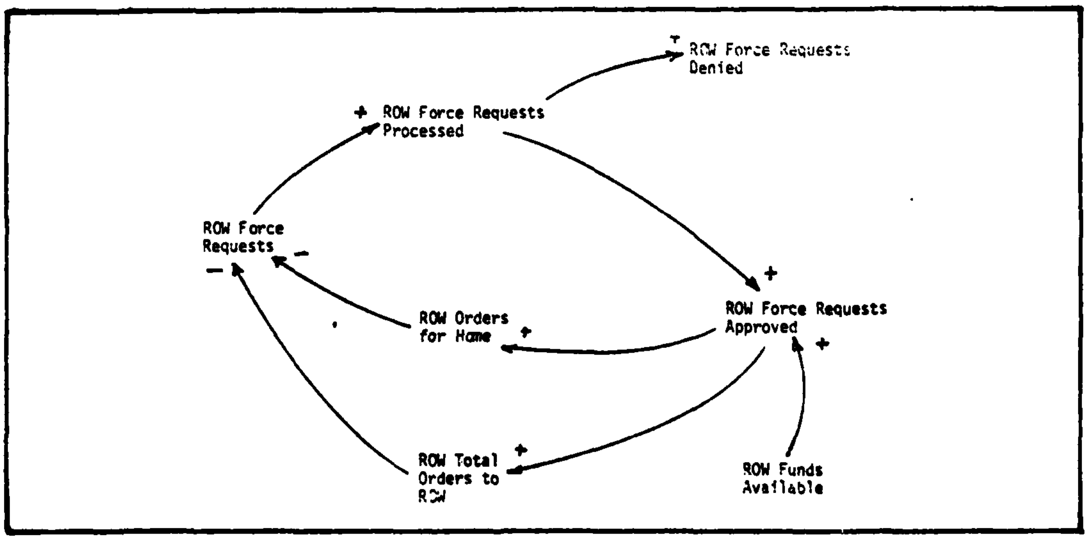


Figure 22. Rest of the World Force Requests Processing Sector---Causal Loop Diagram

are ROW home orders and ROW orders to the ROW. ROW home orders are those orders which are produced at home by those countries which have the available production capability. Examples of some ROW countries that have this capability are the Soviet Union, NATO, Israel, Japan, China, and others. Those ROW orders which are set to the ROW represent the requests which can not, for one reason or another, be filled at home. Figure 22 shows that ROW Force Requests Approved are dependent upon ROW Funds Available however, it does not illustrate the magnitude to this dependence. Further development of the model in Chapter IV will show that ROW Funds Available is indeed a limiting factor when approving arms requests.

It is important to notice that within the diagram of Figure 22 there exist two separate feedback structures which are shown in Figures 23 and 24. These are important, because the distinction between home and foreign orders is an important issue when modeling foreign military sales. Also it can be seen that the causal-loops shown in Figure 23 and and 24 are both negative which implies that the structure will attempt to reach and remain in a steady state condition.

In Figure 22, the level of ROW Unfilled Orders to the ROW can be divided into two catagories as shown in Figure 25. These catagories are ROW Orders to the US and ROW Orders to

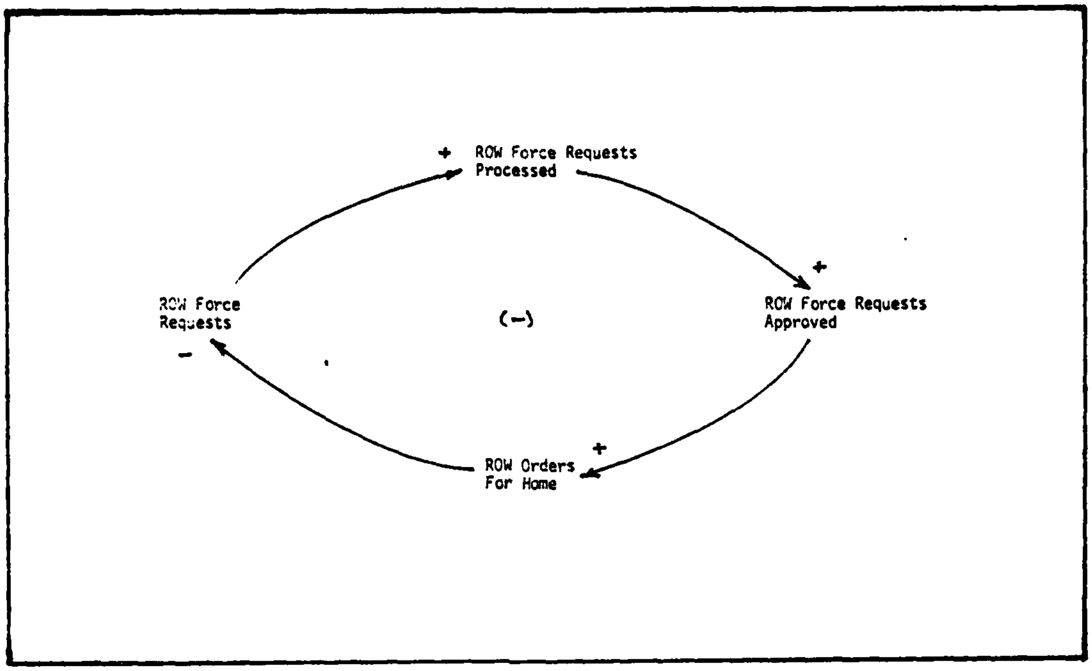


Figure 23. Rest of the World Force Requests Processing Sector (I)---Causal Loop Diagram

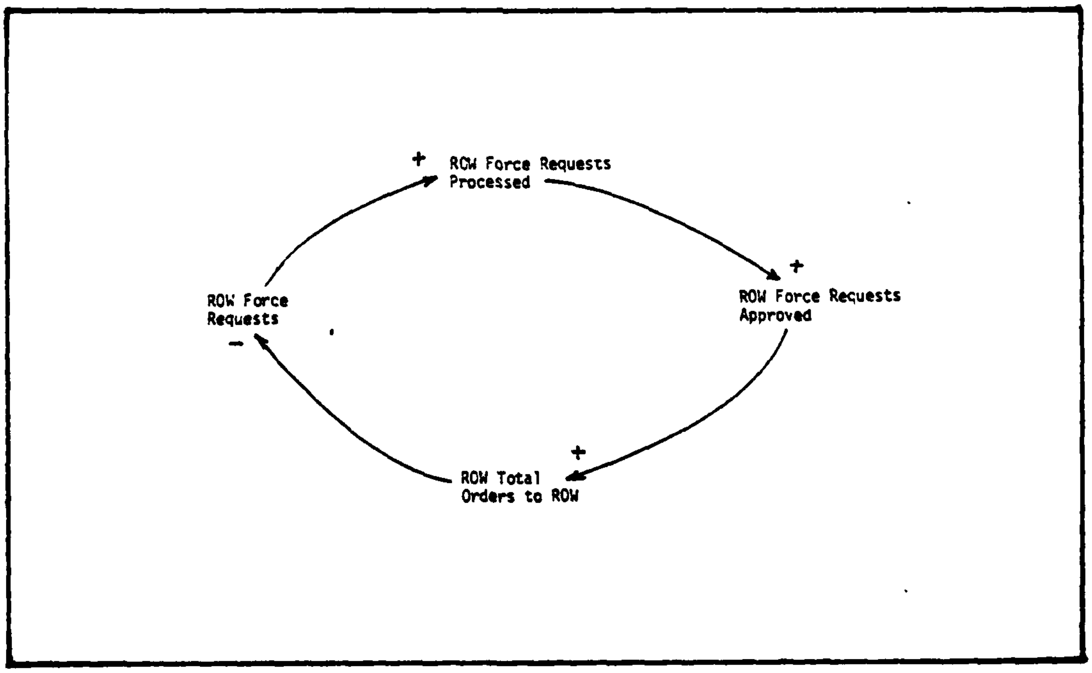


Figure 24. Rest of the World Requests Processing Sector (II)---Causal Loop Diagram

the ROW. When the US receives orders from the ROW, those that are denied are returned to the requesting country which turns around and resubmits the order to a ROW country. The assumption being made is that somewhere in the world there

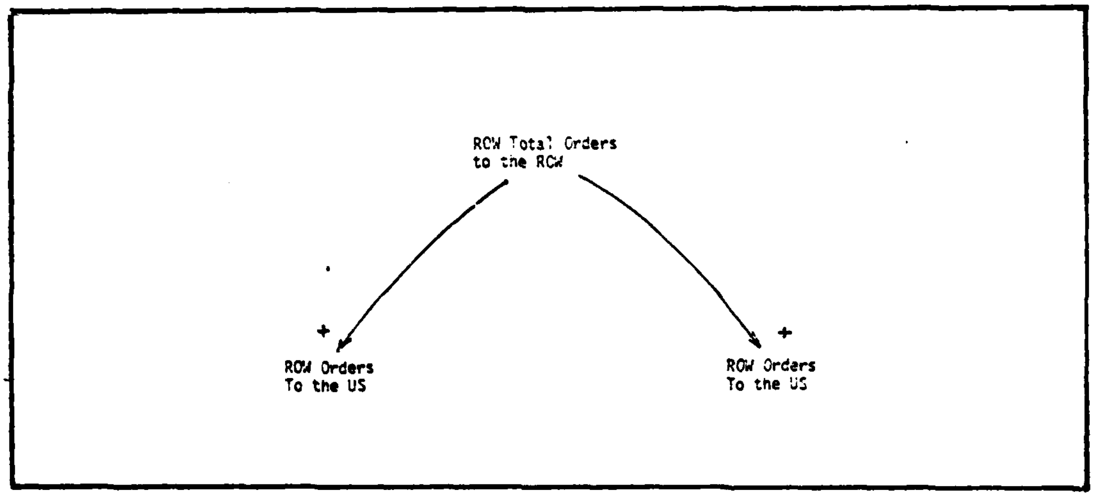


Figure 25. Rest of World Total Orders---
Causal Loop Diagram

will always be a country willing and able to sell what ever arms another country may desire. This may be a bold assumption, however, most arms merchants today are not concerned with the long or short term effects of their arms sales. Also, when a market exists where the demand is ever increasing there will be suppliers willing to invest the necessary funds to produce enough goods to meet the demand. Discussed in the next sector will be the processing of ROW orders.

ROW Orders to US Processing Sector

When orders from the ROW are sent to the United States, they enter the ROW orders to the Processing Sector shown in Figure 26.

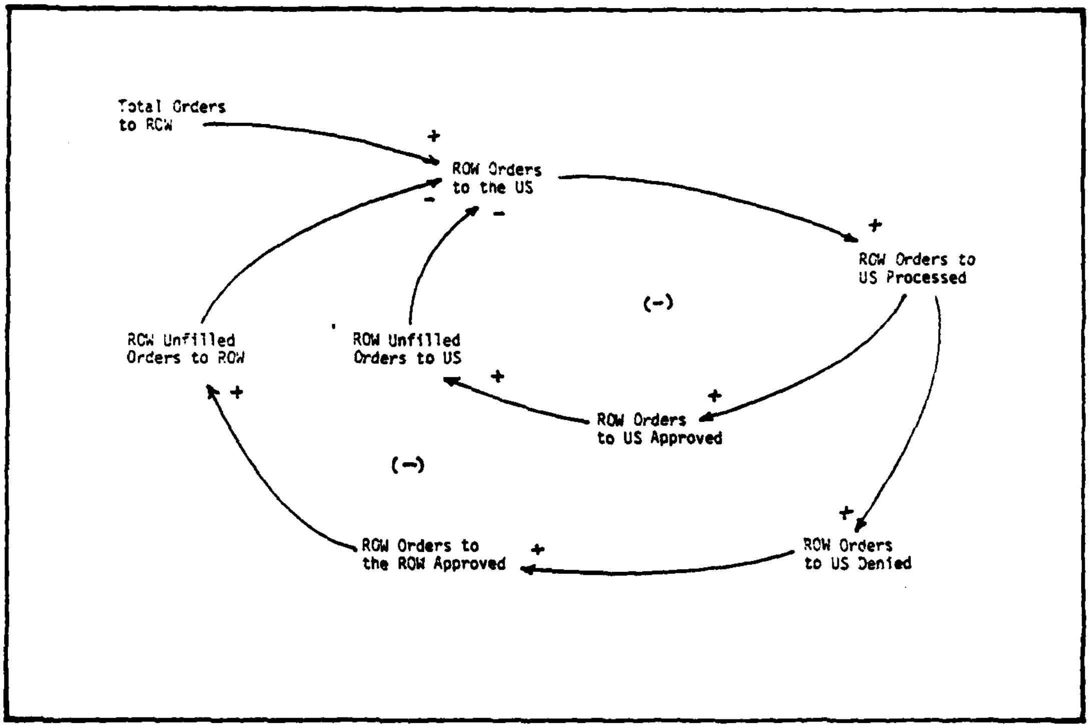


Figure 26. Rest of the World Orders to US Processing Sector--- Causal Loop Diagram

Once received, the ROW orders are processed by the US and are either approved or denied. When the US disapproves an order, the requesting country submits the order to another ROW country. As discussed earlier, any order sent to the ROW will always be approved and become an unfilled order

held by the ROW. The remainder of the orders which are sent to the US by ROW countries are approved as shown in the inner loop of Figure 26. Once approved, these orders become ROW unfilled orders held by the US. To complete the loops, as the US and ROW orders for the ROW increase this will decrease the number of unprocessed orders which were sent to the US. From Figure 26 it can be seen that both loops are negative which suggests that the causal structures will attempt to reach an equilibrium condition. Discussed in the next sector will be the ROW Funds Available Sector which has a great deal of influence on the ROW force requests that are approved.

ROW Funds Available Sector

When isolated from the aggregate casual-loop diagram, the ROW Funds Available Sector appears as shown in Figure 27. Included in this causal-diagram are those variables that interact to determine the amount of funds the ROW will spend on foreign and domestic arms. These variables are the ROW cost of maintaining military forces, cost of the requested weapons system, the ROW gross national product and the ROW payments to the US and ROW for past arms purchases.

Figure 27 shows that the variables that determine the ROW funds available all have a negative effect except for the ROW gross national product. This is what would be expected because as the cost of maintaining a current force,

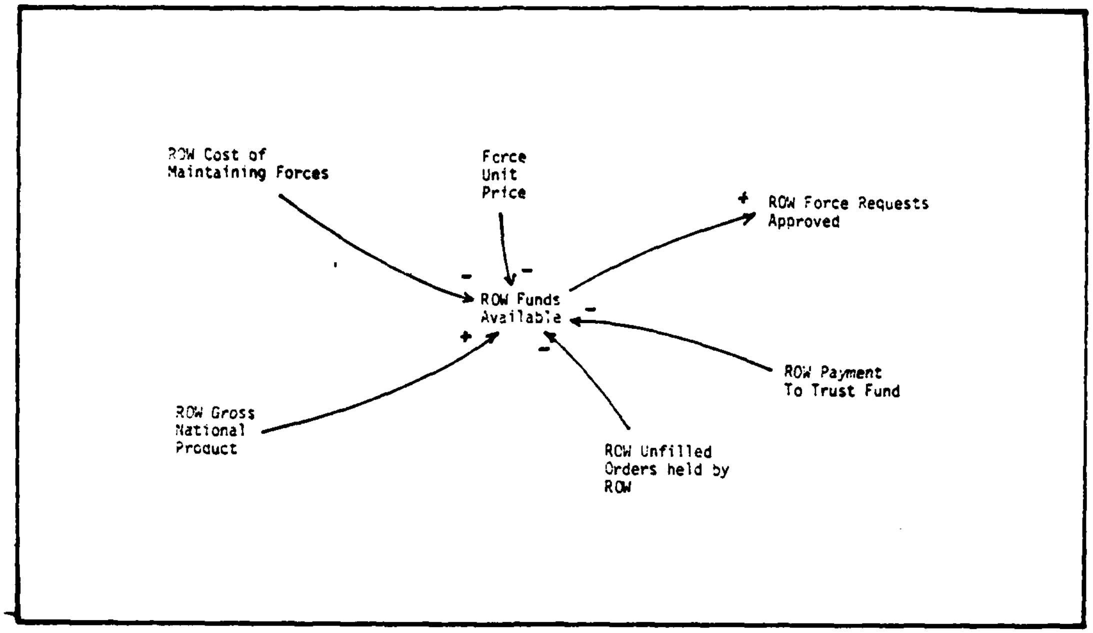


Figure 27. Rest of the World Funds Available Sector --- Causal Loop Diagram

or the price for arms weapons, or payments for past orders exists there will be a drain on the funds that are made available for arms purchases. However, as the ROW gross national product increases there will be an increase (usually) in the amount of funds that are made available for arms purchases.

Figure 27 shows that the variables that determine the ROW funds available all have a negative effect except for the ROW gross national product. This is what would be expected because at the cost of maintaining a current force, as the price for arms increases, or payments for past orders exists there will be a drain on the funds that are made available for arms purchases. However, as the ROW gross national product increases there will be an increase

(usually) in the amount of funds that are made available for arms purchases.

Once the ROW has determined the amount of funds it has available for arms purchases, the ROW can determine which of its force requests will be approved.

This completes the causal-loop structure for the ROW arms transfer process. The remaining sector will be concerned with the effects foreign military sales have on US employment, balance of trade, and gross national product (GNP).

US Employment, Gross National Product and Balance of Trade Sector

The last sector to be discussed will be the US Employment, Gross National Product and Balance of Trade Sector shown in Figure 28. It is in this section that the effects of foreign military sales on the US are observed. From Figure 28 it can be seen that the effects of FMS on US the employment level will be directly based on that income generated from arms sales. Also based on the defense industry income will be the effects FMS's have on US gross national product (GNP). The last variable discussed in this sector is the US Trade Deficit which is a function of the cost of maintaining US forces overseas and the ROW payments to the US for purchased arms.

Although this causal-diagram shown in Figure 28 may seem to be very simple, one must remember all the variables

involved in obtaining values for ROW Trust Fund Payments to US Defense Industry, US Payments to US Defense Industry and US Forces Overseas.

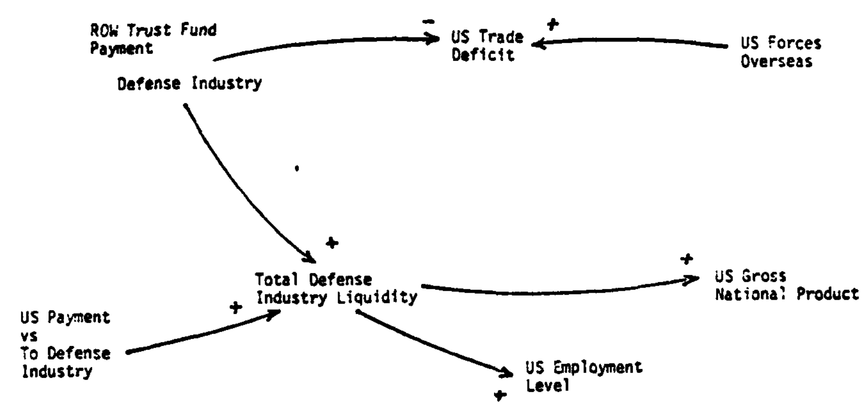


Figure 28. US Gross National Product, Balance of Trade, and Employment Sector---Causal Loop Diagram

Summary

From the discussions on the thirteen causal-loop structures, it appears that most of the causal loops are negative or goal seeking. However, the variables that have a positive influence on the system are difficult to model because they are as difficult to quantify. These variables are ones of perception such as perceived hostility from a neighbor, and regional stability or in-stability which ever may exist.

Chapter IV has provided a detailed discussion of the thirteen sectors which make up the US Arms Transfer Model. Even though the aggregate causal-loop shown in Figure 8 was presented in precis, the overall arms transfer process must be considered as a whole. Each sector plays a significant role in influencing the behavior of the model as it does in the real world. As presented in Chapter III the next step in the Systems dynamics process is to develop the system flow diagrams.

IV. Model Computerization

Introduction

From the discussion of the System Dynamics methodology outlined in Chapter II, the development of a model begins with the definition of a problem, next the causal relationships are developed, and then the system structure is expanded using flow diagrams from which the mathematical equations are developed. The purpose of this chapter, therefore, is to present a discussion of the activities which are taking place in the flow diagrams. Included in this discussion of the flow diagrams are the relevant DYNAMO equations that are used to mathematically represent the processes shown in the figure.

Because of the size and complexity of the Arms Transfer Model, the model flow diagrams and DYNAMO equation will be presented and discussed as thirteen individual sectors. The first paragraph in each sector describes the processes involved in the flow diagrams. Presented and discussed in the remaining portion will be the DYNAMO equations. A complete listing of all variables, their types, sector where defined, and brief description is contained in Appendix B. Appendix A contains the entire listing of the DYNAMO equations that make up the model. This will allow the reader to reference Appendix B for a readable description and Appendix A to see how it was

computed. This discussion of the model will begin with the presentation of the Introductory Sector which sets the stage for further discussion of the flow diagrams and DYNAMO equations.

Introductory Sector

The Introductory Sector shown in Figure 29 sets the stage for the simulation run. The DYNAMO equations in Figure 29 define the number of countries in the model, each countries neighbors the extent of the interaction between countries, and the number of types of armies considered in the model. The following is a discussion of these equations.

Although there are 150 countries in the world, this level of detail is not necessary to portray the dynamic behavior of the system. Therefore, the number of countries in the model were reduced to 19 (NCI) by aggregating or averaging. These 19 countries are shown in Table 1. Where countries could be considered as one, their statistics were aggregated. Where countries could not be aggregated due to political or other reasons reasons, but are essentially similar, their statistics were averaged. Country 18 is a dummy country that is used to complete the arrays in the model. Because the US only purchases limited amounts of arms from the rest of the world (ROW), they are not considered in the model. Therefore, many calculations are only necessary for the first 18 (NCNTRY) countries.

```
*
*
*        ******************************
*        **                          **
*        **    ARMS TRANSFER MODEL   **
*        **                          **
*        ******************************
*
*
*
C NCNTRY=18
C NCI=19
*
*  NCNTRY - NUMBER OF COUNTRIES IN MODEL EXCLUDING THE U.S.
*  NCI - NUMBER OF COUNTRIES IN MODEL INCLUDING THE U.S.
*
*
*        NEIGHBOR ARRAYS
*
T NEIGH(*,1)=2/1/1/8/3/3/5/3/5/19/12/11/12/1/
X 5/12/12/18/10
T NEIGH(*,2)=3/14/5/18/1/5/18/4/8/18/18/13/16/15/
X 14/13/13/18/18
T NEIGH(*,3)=5/17/6/18/6/18/18/9/18/18/18/16/17/16/
X 18/14/14/18/18
T NEIGH(*,4)=14/18/8/18/7/18/18/18/18/18/18/17/18/17/
X 18/17/16/18/18
*
*  NEIGH - TABLE REPRESENTING EACH COUNTRIES NEIGHBORS
*
*
FOR II=1,NCI
FOR I1=1,NCNTRY
FOR I2=1,3
FOR I3=1,4
FOR I4=2,NCNTRY
*
*  II - COUNTRY ARRAY INDEX INCLUDING U.S.
*  I1 - COUNTRY ARRAY INDEX
*  I2 - FORCE ARRAY INDEX
*  I3 - NEICHBOR ARRAY INDEX
*  I4 -
*
*
FNCTN AMAX(2,0,1)
FNCTN AMAXX(3,0,1)
FNCTN AMAXXX(3,0,1)
FNCTN FIND1(6,0,11)
FNCTN FIND2(5,0,11)
FNCTN FIND3(6,0,111)
*
*  FNCTN - EXTERNAL FUNCTIONS USED IN THE MODEL
*
*
N TIME=1982
*
*  TIME - CURRENT TIME OF THE MODEL
*
*
```

Figure 29. Introductory Sector DYNAMO Equations

TABLE I

COUNTRIES OF THE WORLD

No.	Name	Includes	Method of Creation
1	USSR	Soviet Union, Eastern Europe, Mongolia	Aggregation
2	NATO	Western Europe, Greece, Turkey	Aggregation
3	Japan	Japan	Direct
4	Australia	Australia, New Zealand	Aggregation
5	China	China, North Korea	Aggregation
6	S. Korea	South Korea	Direct
7	Taiwan	Taiwan	Direct
8	ASEAN	Malaysian, Thailand, Indonesia, Philippines, Singapore	Aggregation
9	Vietnam	Vietnam, Loas, Cambodia	Aggregation
10	Cuba	Cuba	Direct
11	Libya	Libya, Algeria	Average
12	Egypt	Egypt	Direct
13	Israel	Israel	Direct
14	Iran	Iran, Pakistan	Average
15	India	India	Direct
16	Saudi Arabia	Arabran Peninsula, Jordan	Aggregation
17	Iraq	Iraq, Syria, Lebanon	Aggregation
18	Dummy Country		
19	United States	United States, Canada	Aggregation

To determine each countries neighbors a neighbor array (NEIGH) is established. Because of a restriction on the size of the mathematical model each country was only allowed to have four neighbors. The following is an example of how the NEIGH array is used. First, select a country from Table I, say number one which is the USSR. Then looking at the NEIGH arrays the numbers in the first position of each table are 2,3,5, and 14. Going back to Table I, countries 2,3,5, and 14 correspond to NATO, Japan, China, and Iran, which have been selected as the USSR's more important neighbors. To determine any countries neighbors the same procedure can be followed.

When an equation holds for more than one value of a subscript a FOR variable is used to specify the range of values over which the equation applies. The first two FOR variables determine the extent of interaction between the countries of the model. The third FOR variable determines the number of weapon types that are considered in the model. Because of the almost unlimited number of weapon types and the limit on the models size, only three types of weapons were considered. The three systems considered were tactical nuclear weapons; tactical aircraft, and surface to air missiles (SAM). Tactical nuclear weapons were considered because of their influence on the composition of a country's military inventories. The fourth FOR variable determines which countries neighbor is being discussed in the model

and the fifth FOR variable is used to exclude the USSR from a specific calculation. The remaining equations in the Introductory Sector define external functions (FNCTN) and the time reference (TIME) of the model. The remainder of this chapter will present the 13 sectors that make up the US Arms Transfer Model.

US Force Requests Sector

The flow diagram for the US Force Requests Sector is shown in Figure 30. From the diagram it can be seen that US force requests are generated by the US Force Requests Rate (USFRRT). After force requests have been generated they are processed through a delay which represents the time required for the President and Congress to make a decision concerning the request. Processed requests are then divided into force requests that are approved which become US Unfilled Orders (USUO) and those that are denied which exit the system. This division of approved and denied requests is caused by two rates, US Force Requests Approval Rate (USFRAR) and US Force Requests Denial Rate (USFRDR). These rates are directly affected by the pressure placed on Congress for Force Appropriations (USPCFA).

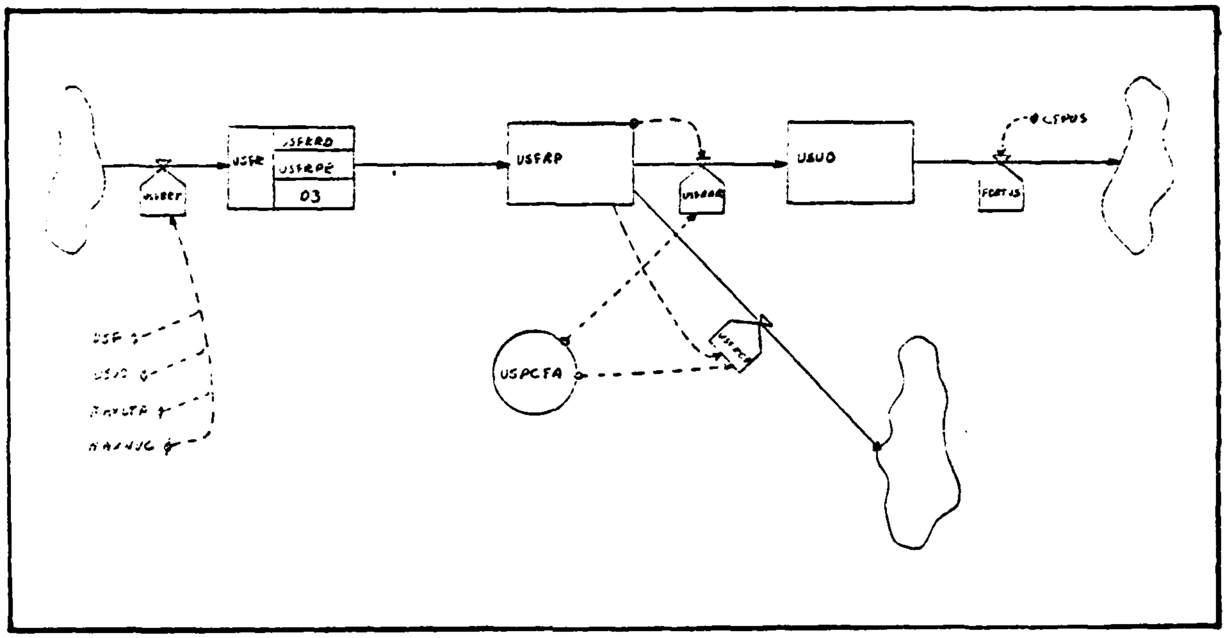


Figure 30. US Force Requests Sector---Flow Diagram

R USFRRT.KL(1) = MAX(MAXNUC.K - USF.K(1) - USUD.K(1),Ø

R USFRRT.KL(I) = MAX(MAXLTF.K - NWF(I)*MAX(USF(1)

- MAXNUC.K,Ø) - SUMV(USF.K,2,3)

- SUMV(USUO-K,2,3),Ø)

A MAXNUC.K = AMAX(NUCT.K,NCNTRY)

A MAXLTF.K(I1) = AMAX(ROWLTF.K,NCNTRY)

A NUCT.K(I1) = RF.K(I1,1)*USHOST(I1)

A ROWLTF.K(I1) = SUMV(RF.K(I1,*),2,3)

US Force Requests Rate (orders/unit time). As mentioned earlier, the arms transfer model considers three weapons systems, tactical nuclear, tactical aircraft and surface to air missiles. Because of the effects nuclear weapons have on the balance of power, the determination of their influence in the model requires a separate equation in several instances. In this instance the US request rate for tactical nuclear weapons equals the maximum nuclear threat towards the US(MAXNUC) minus the existing US tactical

nuclear force (USF) minus the tactical nuclear weapons on order (USUO). The second rate equation shown is used to determine the rate at which the US requests conventional weapons. The US request rate for conventional weapons is equal to the maximum single country conventional threat towards the US(MAXLTF) minus the nuclear weapons fraction (NWF) times the difference between the US and hostile countries tactical nuclear forces minus the sum of US current forces and forces on order. In both rate equations negative rate has no meaning, therefore they are not allowed to go below zero.

```
L    USFR.K(I2) = USFR.J(I2) + DT * (USFRRT.JK(I2)
                    - USFRPRSK(I2))

R    USFRPR.KL(I2) = DELAY3(USFRRT.JK(I2), USFRPD)

C    USFRPD = .75
```

US Force REquests (number of orders). The level of US force requests is determined by the US force requests rate (USFRRT) and US force requests processing rate (USFRPR). The rate at which US force requests are processed is equal to a third order delay which is defined by USFRRT and the length of the processing delay (USFRPD) which is equal to 3/4 of a year. The order of the delay (1st, 3rd, etc.) is used to describe how requests are processed. In a first order delay, orders would be processed quickly and then level off in time. In a third order delay orders are processed slowly in the beginning and then increase quickly over a short period of time and then level off. The higher order of delay will result in a quicker increase over a shorter period of time. The shape of the delay curves are shown in the DYNAMO User's Manual (Ref: 12).

```
L    USFRP.K(I2) = USFRP.J(I2) + DT * (USFRPR.JK(I2)
                    - USFRAR.JK(I2) - USFRDR.JK(I2))

R    USFRAR.JK(I2) = USPCFA.K * USFRP(I2)

R    USFRDR.JK(I2) = (1 - USPCFA.K) * USFRP(I2)
```

US Force Requests Processed (number of orders). The level of force requests processed is determined by the rate at which requests are processed (USFRPR) minus the rate they are approved or denied. The US approval rate (USFRAR) is equal to the level of processed requests (USFRP) times the pressure placed on Congress for force appropriations (USPCFA). US force requests denial rate (USFRDR) is equal to the level of force requests times (1 - USPCFA).

L USUO.K(I1) = USUO.J(I2) + DT * (USFRAR.JK(I2)

- FDRTUS.JK(I2)

R FDRTUS.JK(I2) = CFPUS.K(NCI,I2)

US Unfilled Orders (number of orders). The level of US unfilled orders is a function of the US force requests approval rate (USFRAR) and the US force deployment rate (FDRTUS). The US force deployment rate is equal to the number of completed orders (CFPUS).

The next flow diagram and set of equations deals with the pressure that is placed on Congress for force appropriations.

US Pressure on Congress For Force Appropriations Sector

The flow diagram for this sector is shown in Figure 31. This sector represents the US Government's decision making process for defense purchases. US Pressure on Congress For Force Appropriations (USPCFA) is composed entirely of auxiliaries and constants. The important factors which affect USPCFA are US Force Requests (USFR), US Force Inventory (USF), US Gross National Product (USGNP), and the perceived threat of the ROW towards the US. USPCFA has a major effect

in determining US Defense Appropriations, which in turn determines the rate at which US arms requests are approved.

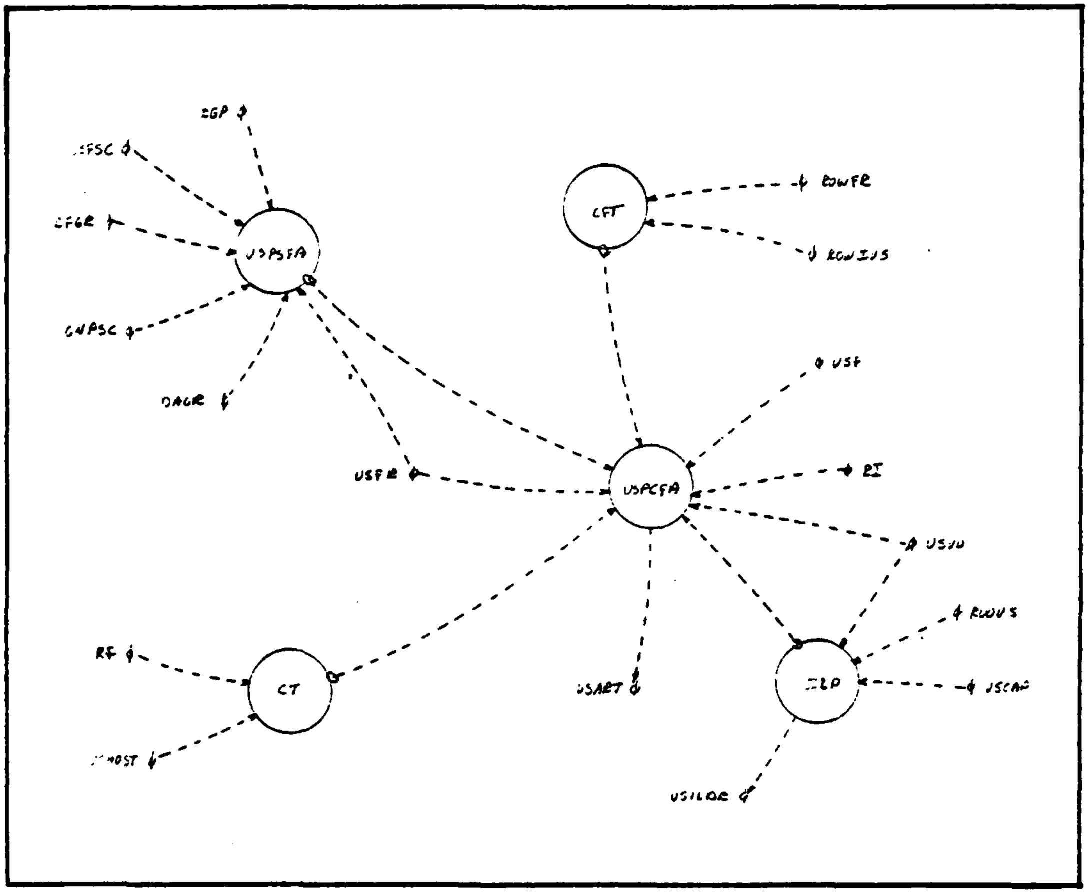


Figure 31. US Pressure on Congress For Force Appropriations Sector---Flow Diagram

A USPCFA.K = (W2 * SUM(CFT.K)/RI.K + W3 * ILP.K
+ W4 * USPCFA.K + W5 * (SUM(CT.K)
- SUM(USF.K) - SUM(USUO.L))/SUM(USFR.K))
/SUM(CFT.K)/RI.K

```
A    CFT.K(I1) = SUM(ROWFR.K) * ROWIUS(I1)

A    CRF.K(I1) = SUMV(RF.K(I1,*),1,3) * USHOST(I1)

A    CT.K(I1) = SUMV(RF.K(I2,*),1,3) * USHOST(I2)

A    RI.K = SUM(ROWFR.K)
```

US Pressure on Congress for Force Appropriations (dimensionless). From the above equation it is obvious that the pressure placed on Congress for appropriations is very complicated. USPCFA is determined by the total Country Force Requests (CFT), Industry Lobby Pressure (ILP), US Popular Support for Force Appropriations (USPCFA), Single Country threat to the US (CT), US Force Inventory (USF), US Unfilled Orders (USUO), US Force Requests (USFR), and a Regional Instability factor (RI). The weighting coefficients (W1-W5) used in calculating USPCFA determines the level of influence each variable has on Congress. USPCFA represents a percentage and will therefore have a value between zero and one.

The next flow diagram and set of equations will be concerned with the production of US and ROW unfilled force requests by US industry.

US Force Production Sector

The diagram for this section is shown in Figure 32. The US Planned Force Production Rate (USPRUS) determines the rate at which US and ROW unfilled orders are put into production. PFPRUS is a fraction of the number of unfilled force requests held by the US and the maximum production capacity of the US defense industry. The rate at which US Forces in Production (FIPUS) are produced is determined by the US Force Production Rate (FPRTUS) which is a fraction of a delay. This US Force Production Delay (FPDUS) determines

the length of time required to produce each unit in production. Completed US Force Requests (CFPUS) are then deployed to US Forces CONUS (USFC) or ROW Force Inventory (RF).

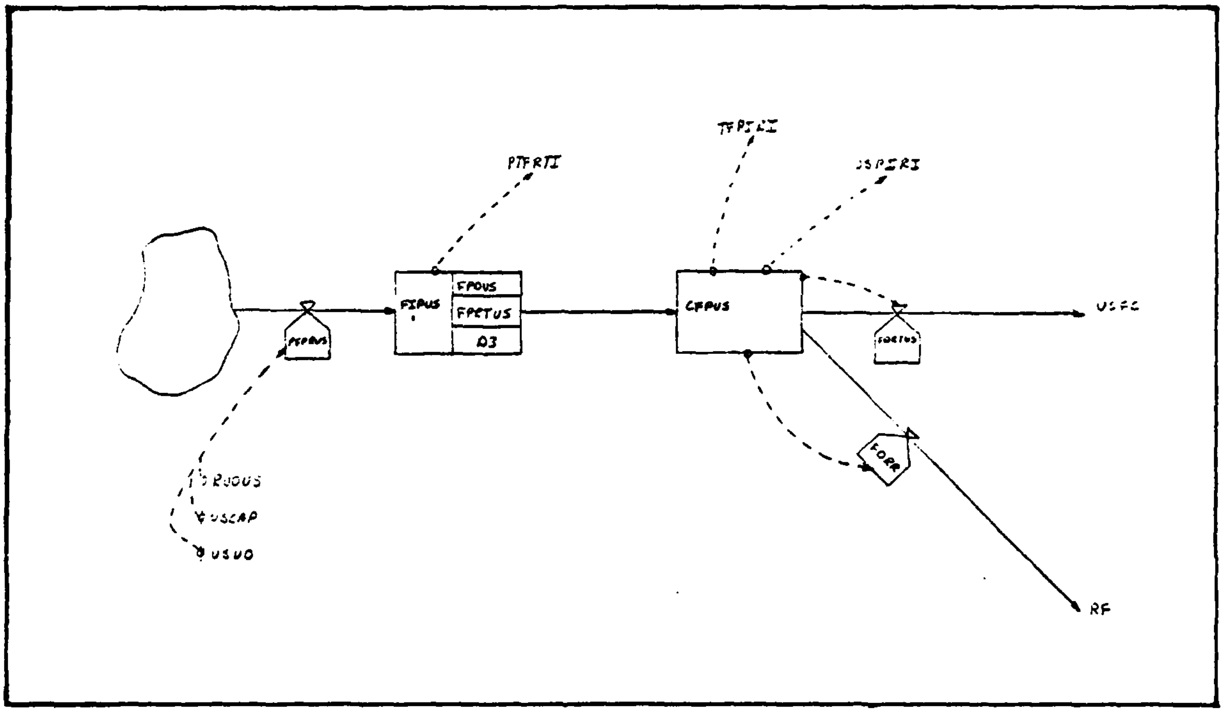


Figure 32. US Force Production Sector---Flow Diagram

R PFPRUS.KL(I1,I2) = RUOUS.K(I1,I2) * MAX(Ø,USCAP.K(I2) - USUO.L(I2))/SUMU(RUOUS.K(*,I2), 1, NCNTRY)

R PFPRUS.KL(NCI,I2) = MIN(USCAP.K(I2) , USUO.K(I2))

US Planned Force Production Rate (weapons/unit time). The first rate equation shown computed the rate at which the US will produce the ROW unfilled orders it approved. This rate is determined by each country's fraction of the total ROW unfilled orders held the US times the available industrial capacity for producing arms. There is one important assumption made here that needs to be mentioned. The model assumes that the production of US unfilled orders will always have priority over ROW unfilled orders. Because a negative planned production rate has no meaning this rate equation is not allowed to be less than zero. The second equation shown determines the planned production rate of US forces which is equal to the maximum US production level (USCAP) or the number of US Unfilled Orders (USUO) which ever is smaller.

```
L   FIPUS.K(I1,I2) = FIPUS.J(I1,I2) + DT * (PFPRUS.JK(I1,I2)
                         - FPRTUS.JK(I1,I2))

R   FPRTUS.KL(I1,I2) = DELAY3(PFPRUS.JK(I1,I2) , FPDUS(I2)
```

US Forces in Production (number of weapons). The level of US Forces in Production (FIPUS) is determined by the US Planned Production Rate (PFPRUS) and the US Force Production Rate (FPRTUS). The FPRTUS rate is equal to delay which accounts for the time required to produce each order.

```
L   CFPUS.K(I1,I2) = CFPUS.J(I1,K2) + DT * (FPRTUS.JK(I1,I2)
                        - FDRR.JK(I1,I2))

L   CFPUS.K(NCI,I2) = CFPUS.J(NCI,I2) + DT * (FPRTUS.JK)
                         (NCI,I2) - FDRTUS.JK(I2))

R   FDRR.KL(I1,I2) = CFPUS(I1,I2)

R   FDRTUS.KL(I2) = CFPUS(NCI,I2)
```

US Completed Force Production (number of weapons). The level of US Completed Force production (CFPUS) is shown to be determined by two equations. The first equation determines the level of ROW unfilled orders produced by the US and the second equation computes the same value except for the US. These forces produced for the ROW are deployed by the ROW Force Deployment Rate (FDRR) and become part of the ROW Force Inventory (RF). Compiled US forces are deployed by the US Force Deployment Rate (FDFTUS) which become part of US CONUS Forces (USFC).

The next flow diagram and set of equations will be concerned with the deployment of US forces overseas.

Deployment of US Forces Overseas Sector

The US Deployment of Forces Overseas Sector is shown in Figure 33. As US force productions are completed they are deployed to US Forces in CONUS (USFC). At the time the completed forces are either deployed overseas (USFO) or remain in the US. The variable that controls the deployment of US forces overseas is the US Forces Overseas Deployment Rate (USFODR). USFODR allows forces to be deployed overseas and returned from overseas. US forces stationed in the CONUS and overseas are retired from use by the US Forces Overseas Retirement Rate (USFORR) and the US CONUS Forces Retirement Rate (USCFRR).

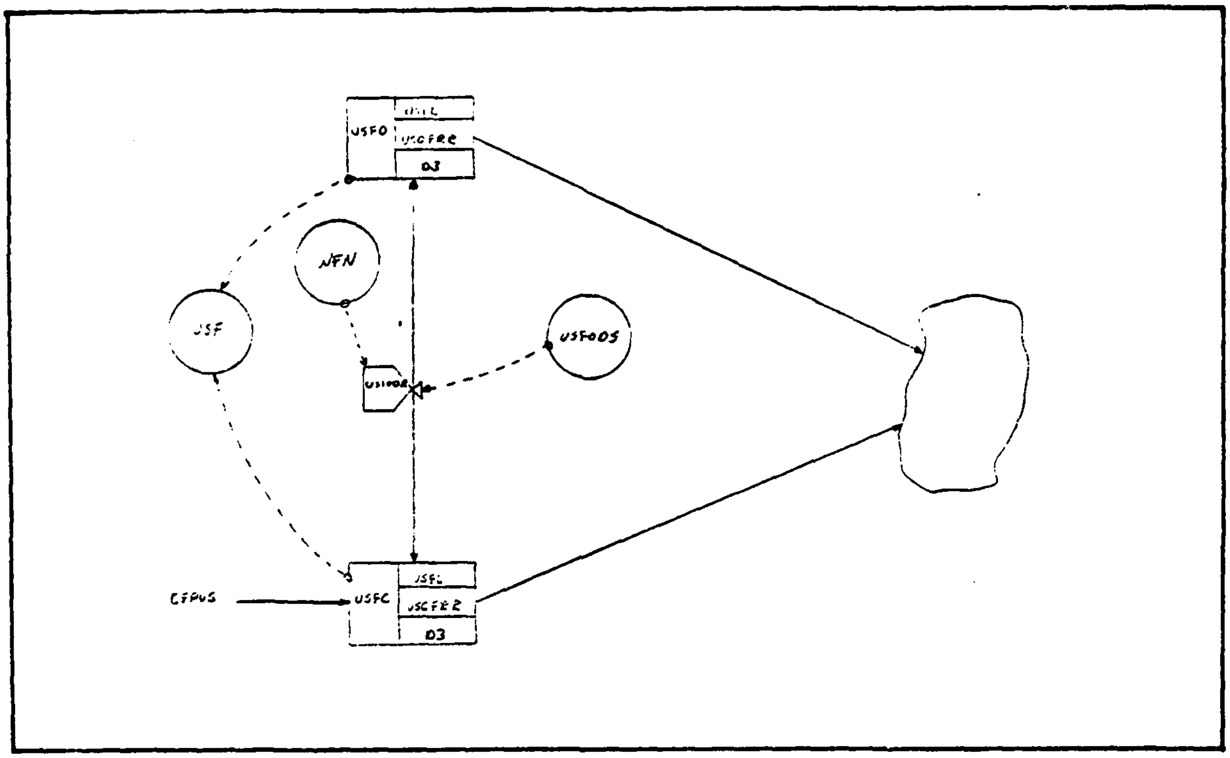


Figure 33. Deployment of US Forces Overseas Sector---
Flow Diagram

```
L    USFC.K(I2) = USFC.3(I2) + DT * (FDRTUS.JK(I2)
                  - SUMV(USFODR.JK(*,I2),1, NCNTRY)
                  - USCFRR(I2))

R    USCFRR.KL(I2) = DELAY3(FDRTUS.JK(I2) , USFL(I2))
```

US Forces CONUS (number of weapons). The level of US Forces CONUS (USFC) is determined by the US Force Deployment Rate (FORTUS) minus the total number of forces stationed overseas (USFODR) and the number of forces that are retired (USCFRR). US forces retire over a constant period of time given by US Force Life (USFL).

```
R    USFODR.KL(I1,1) = MIN((MAX(Ø,(AMAXXX(NFN.K,NCNTRY,I1)
                       - RF.K(I1,1) - USFO.K(I1,1))) * MIN
```

```
                    (USIROW(I1) , ROWIUS(I1))) , ((USF.K(1)
                    * OSFRAC(1)) - SUMV(USFOR.K(X,1),1,
                    NCNTRY)))
R   USFODR.KL(I1,I) = MIN((MAX(Ø,ROWFR.K(I1) - SUMV
                    (RF.K(I1,X),1,3) - SUMV(USFO.K(I1,*),
                    1,3) - USFODS.K(I1,1))) * MIN(USIROW
                    (I1) , ROWIUS(I2))) , MAX(Ø,SUM(USFTO)
                    - SUM(USFO))))
A   NFN.K(I1,I2,I3) = NFK(I1,I2,K3) * RHOST(I1,I3)
A   NF.K(I1,I2,I3) = FIND1(RF.K,NEIGH, I1,I2,I3,NCI)
A   USFTO,K(I2) = USF(I2) * OSFRAC(I2)
```

US Forces Overseas Deployment Rate (weapons/unit time). As in earlier cases two equations are necessary to describe the deployment of US forces overseas. The first equation determines the rate at which the US deploys nuclear weapons overseas. The rate of nuclear weapons deployed to an overseas country is equal to the maximum perceived nuclear threat from a neighboring country minus the combined US overseas and ROW country tactical nuclear inventory. Then depending on the ROW Importance to the US (ROWIUS) and the US Importance to the ROW (USIROW) the level of weapons to be deployed is corrected. The second rate equation computes the deployment of US conventional forces overseas. This equation is a function of ROW Force Requests (ROWFR), ROW Force Inventory (RF), US Forces Overseas (USFO), and the maximum amount of US Forces Deployable Overseas (USFO). In both equations the rate of force deployments is multiplied by one of two foreign relations factors which are the ROW Importance to the US (ROWIUS) and the US Importance to the ROW (USIROW). The auxiliary equation that determines the threat from a neighboring country (NFN) is determined by the neighboring country's force size (RF) times the ROW's perceived hostility from that country.

```
L   USFO.K(I1,I2) = USFO.J(I1,I2) + DT * (USFODR.JK(I1,I2)
                - USOFRR.JK(I1,I2))
```

R USOFRR.KL(I1,I2) = DELAY3(USFODR.JK(I1,I2) , USFL(I2))

US Forces Overseas (number of weapons). The level of US Forces Overseas (USFO) is determined by the US Forces Overseas Deployment rate (USFODR) and the US Forces Overseas Retirement Rate (USOFRR). US overseas forces are assumed to retire over the same period of time (USFL) as do US CONUS forces.

The next flow diagram and set of equations will be concerned with the development of US capital which determines the maximum amount of forces the US can produce.

US Capital Production Sector

The flow diagram for the US Capital Production Sector is shown in Figure 34. This sector plans, produces and retires production capital for the US defense industry. Materials for new capital enter the system through the US Planned Capital Production rate (USPCPR). Once complete, US Capital in Production (USCIP) becomes US Capital Inventory (USCAP) through the US Capital Production Rate (USCPR). The rate at which capital is retired is determined by the US Capital retirement Rate (USCRRT).

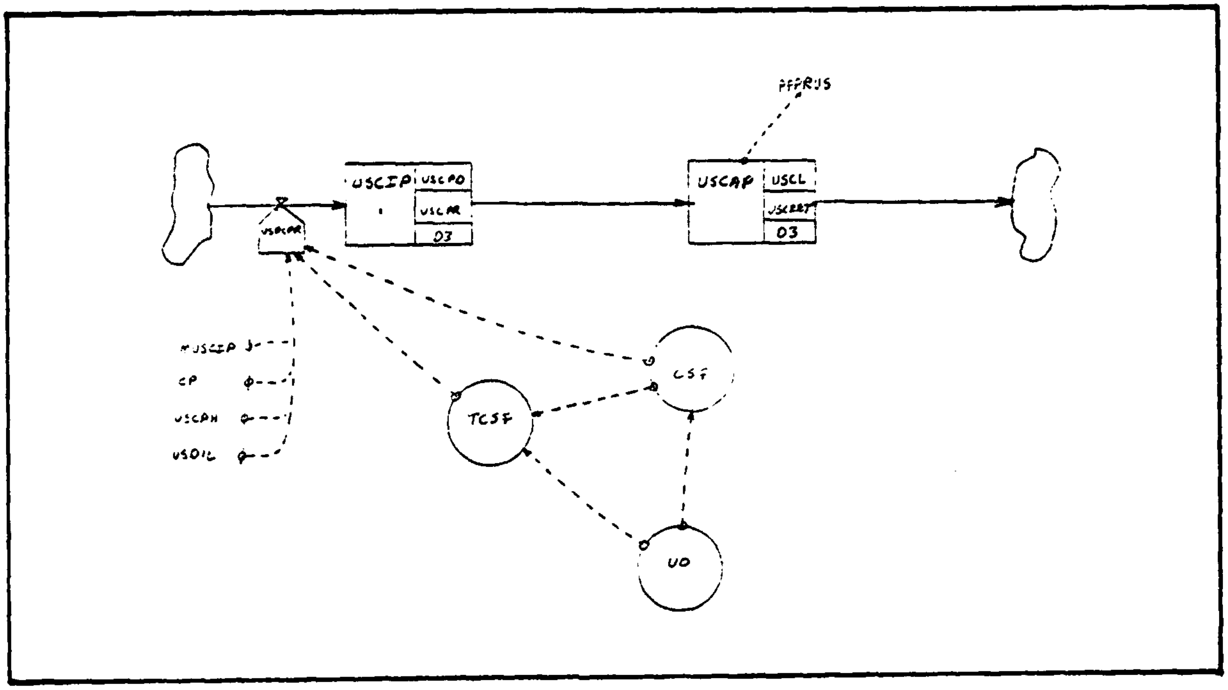


Figure 34. US Capital Production Sector---Flow Diagram

R USPCPR.KL(I2) = MIN(SMOOTH(CSF.K(I2) , USCPH) , USDIL.K /CP(I2) * MUSCIP * SMOOTH(CSF.K(I2) , USCPH)/SMOOTH(TCSF.K, USCPH))

A CSF.K(I2) = UO.K(I2)/FPDUS(I2) - USCAP.K(I2)

A TCSF.K(I2) = SUMV(CSF.K(I2))

A UO.K(I2) = USUO.K(I2) + SUMV(RUOUS.K(*,I2),1,NCNTRY)

US Capital Production Rate (capital/unit time). The US Capital Production Rate (USPCPR) is determined by the US Capital Shortfall (CSF), US Defense Industry Liquidity (USDIL), Capital Price (CP), Fractions of Defense Industries Funds Available for Capital Production (MUSCIP), and Total Capital Shortfall (TCSF). US CSF is equal to the number of US industry unfilled orders (UO) divided by the US Force Production Delay (FDPUS) minus the current US Capital Inventory (USCAP).

L   USCIP.K(I2) = USCIP.J(I2) + DT * (USPCPRSK(I2)

- USCRRT.JK(I2))

R   USCRRT.KL(I2) = DELAY3(USCPR.JK(I2) , USCPD)

US Capital in Production (units of capital). The level of US Capital Production (USCIP) is determined by the difference between the US Capital Planned Capital Production Rate (USPCPR) and the actual US Capital Production Rate (USCPR). The USCPR is equal to a 3rd order delay to account for the time necessary to produce the capital.

L   USCAP,L(I2) = USCAP.J(I2) + DT * (USCPR.JK(I2)

- USCRRT.JK(I2))

R   USCRRT.KL(I2) = DELAY3(USCPR.JK(I2) , USCL)

US Capital Inventory (units of capital). The level of US Capital Inventory (USCAP) is determined by US Capital Production Rate (USCPR) and US Capital Retirement Rate (USCRRT). The rate at which US capital retires is described by a 3rd order delay with a constant US Capital Life (USCL) expectancy.

The next flow diagram and set of equations presented will be concerned with the funds the defense industry receives from the US and ROW in payment for arms purchases.

US Defense Industry Liquidity Sector

As Figure 35 depicts, US Defense Industry Liquidity (USDIL) receives its funds from two sources. The first source is the Trust Fund (TF) which is controlled by the US Government. When ROW orders are approved by the US, the ordering country must make payments to the TF. These monies are then paid to the defense industry at a rate determined

by the Trust Fund Payment to Defense Industry Rate (TFPIR). The second source of income for the US Defense Industry is US Force Appropriations (USFA). These appropriations are received from Congress by means of the US Appropriations Rate (USART) which are then paid to industry (USPIR). The US defense industry disposes of their funds through the US Defense Industry Liquidity Rate (USILDR).

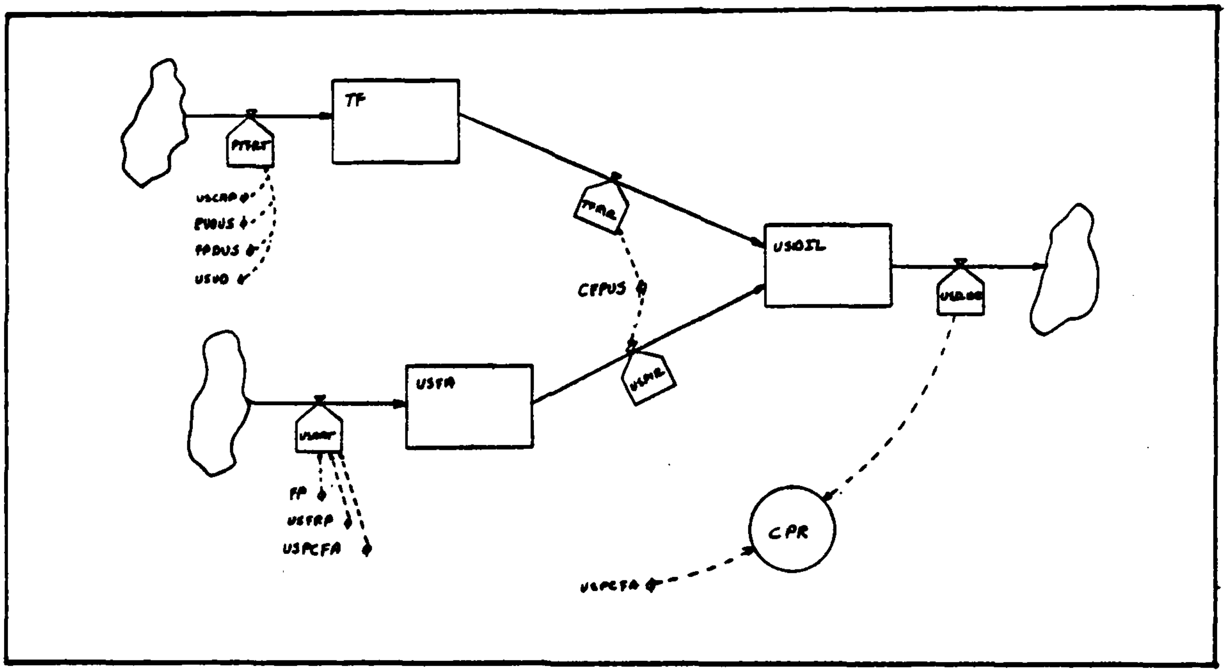


Figure 35. US Defense Industry Liquidity Sector---
Flow Diagram

```
R    PTFRT.KL(I1) = SUMV(PTFRTI.K(I1,*), 1,3)

A    PTFRTI.K(I1,I2) = FP(I2) * MIN(RUOUS.K(I1,I2)/FPDUS(I2) ,
                       RUOUS.K(I1,I2)/SUMV(RUOUS.K(*,I2) ,
                       1,NCNTRY * MAX(USCAP.K(I2) - USUD.K
                       (I2/FPDUS(12),Ø))
```

L TF.K(I1) = TF.J(I1) + DT * (PTFRT.JK(I1) - TFPIR.JK(I1))

R TFPIR.KL(I1) = SUMV(TFPIRI.K(I1,*),1.3)

A TFPIRI.K(I1,I2) = FP(I2) * CFPUS.K(I1,I2)

Payment to Trust Fund Rate (dollars/unit time). The rate at which the ROW pays the Trust Fund (TF) is a function of the Force Price (FP), ROW Unfilled Orders to the US (RUDUS), US Production Delay (FPDUS), US Capital Inventory (USCAP), and US Unfilled Orders (USUO). The FP multiplied by the fractions of forces that are completed determine the Payments to Trust Fund Rate (PTFRT) which is described by the intermediate rate calculation (PTETI). The level of the Trust is influenced by the Payment to Trust Fund Rate (PTFRT) and the Payment to Defense Industry Liquidity Rate (TFPIR).

R USART.KL(I2) = USPCFA.K * USFRP.K(I2) * FP(I2)

L USFA.K(I2) = USFA.J(I2) + DT * (USART.JK(I2)

- USPIR.JK(I2))

R USPIR.KL(I2) = SUM(USPIRI.K)

A USPIRI.K(I2) = FP(I2) * CFPUS.K(NCI,I2)

US Appropriations Rate (dollars/period). The US Appropriations Rate (USART) is equal to the fraction of US Force Requests Processed (USFRP) approved by Congress (USPCFA) times the Force Price (FP). USART and US Payments to Defense Industry Rate (USPIR) determines the changes that occur in the level of US Force Appropriations (USFA). The USPIR rate is equal to the FP times US Completed Force Production (CFPUS). PTFRT and USART are very similar except PTFRT represents ROW payments and USART are US payments to the US defense industry.

L USDIL.K = USDIL.J + DT * (SUM(TFPIR.JK) + USPIR.JK

- USILDR.JK)

R USILDR.KL = ILP.K * LP + SUM(FPR.K) + SUM(CPR.K)

+ DC * USPIL.K

```
A   FPR.K(I2) = (SUMV(FPRTUS.JK(*,I2),1,NCNTRY)
                  + FPRTUS.JK(NCI,I2)) * FC(I2)
A   CPR.K(I2) = USCPR.JK(I2) * CP(I2)
```

US Defense Industry Liquidity (millions of dollars). Payment of Funds to the US defense industry for arms purchases accumulate as US Defense Industry Liquidity (USDIL). The rate at which the defense industry receives funds is equal to TFPIR and USPIR which were described earlier. The rate at which the defense industry spends its funds is determined by the US Defense Industry Liquidity Depletion Rate (USILDR). This rate is equal to the Industry Lobby Pressure (ILP) times the Lobby Price (LP) plus the Force Payment Rate (FPR), Capital Payment Rate (CPR), and a Disbursement Constant (DC) times USDIL.

ROW Force Requests Sector

The ROW Force Requests Sector shown in Figure 36, calculates each countries force requests without considering different technology levels. ROW Force Requests (ROWFR) are based on several factors computed within the model. These factors include perceived US Hostility (USHOST), ROW Force Inventory (RF), ROW Unfilled Orders held by US (RUOUS) and ROW (RUOR), US Forces Overseas (USFO), perceived Regional Instability (RI), and the US Force Inventory (USF).

It is important to note that the level of ROW Funds Available (RAVAL) is not taken into consideration when ROWFR is calculated. This is because ROWFR is an indicator of the perceived instability within the region of the ROW country that is requesting arms. By considering the ROW funds available (RAVAL) the number of ROW force requests (ROWFR) would be restrained and therefore no longer give an accurate picture of the perceived regional instability.

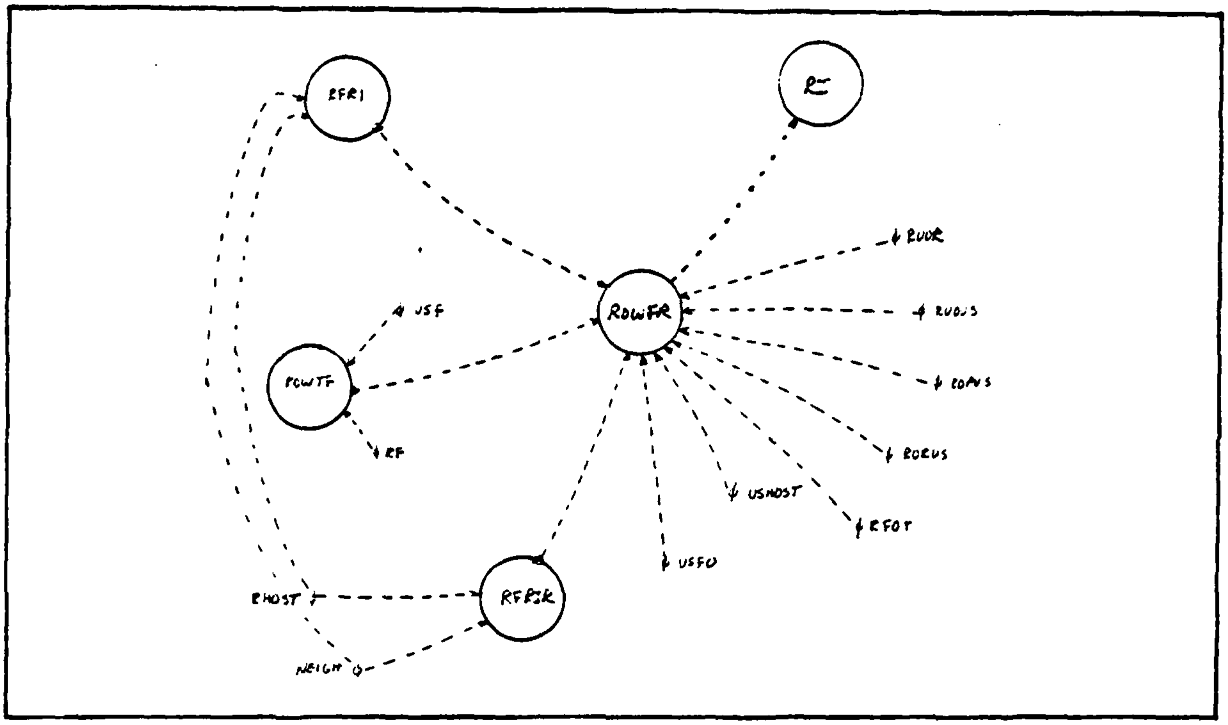


Figure 36. ROW Force Requests Sector---Flow Diagram

```
A    ROWFR.K(I1) = MAX(AMAXX(RFRI.K,NCNTRY.I1) + USTF.K
                   * USHOST (I1) - ROWTF.K(I1) - SUMU(RFRA.K
                   (I1,*),1,3) - SUMV(RFDT.K(I1,*),1,3)
                   - SUMV(RORUS.K(I1,*),1,3) - SUMV(ROPUS.K
                   (I1,*),1,3) - SUMV(RUOUS.K(I1,*),1,3)
                   SUMV(RVOR.K(I1,*),1,3) - SUMV(USFO.K
                   (I1,*),1,3,Ø)
A    RFRI.K(I1,I3) = FIND3(RHOST,NEIGH,ROWTF,I1,I3,NCI)
A    RFIR.K(I1,I3) = RHOST(I1,I3) * FIND2(ROWTF.K,NEIGH,
                     I1,I3,NCI)
A    USTF.K = SUM(USF.K)
A    ROWTF.K(I1) = SUMV(RF.K(I1,*),1,3)
A    ROWTF.K(NCI) = USTF.K
```

ROW Force Requests (number of weapons). The number of ROW Force Requests (ROWFR) depends upon the factors shown in the equation above. ROWFR equals the maximum ROW Hostile Neighbor Force Inventory (RFRI) plus the total US Force Inventory (USTF) times perceived US Hostility towards the ROW (USHOST) which takes into account the US foreign relationship with that ROW country minus the sum of ROW forces in all phases of processing and US Forces Overseas (USFO). Because levels and rates change within the model in order to compensate the actual number of ROW forces in the system several variables must be considered. These variables are the Total ROW Force Inventory (ROWTF), ROW Force Requests Approved (RFRA), ROW Foreign Orders Total (RFOT), ROW Orders Received by the US (RORUS), ROW Orders Processed by the US (ROPUS), ROW Unfilled Orders held by the US (RUOUS) and ROW Unfilled Orders held by ROW (RUOR).

After determining the ROW force requests the next section to be addressed will be concerned with processing of ROW force requests.

ROW Force Requests Processing Sector

The US Force Requests Processing Sector shown in Figure 37, generates and processes the ROW requests for weapons. Requests are generated by the ROW Force Approval Rate (RFRART) and directed into the level containing the ROW Force Requests Approved (RFRA). These requests are then divided into orders that can be filled at home and those which become orders to the ROW. The amount of orders ROW countries produce at home is dependent upon the production capacity of that nation.

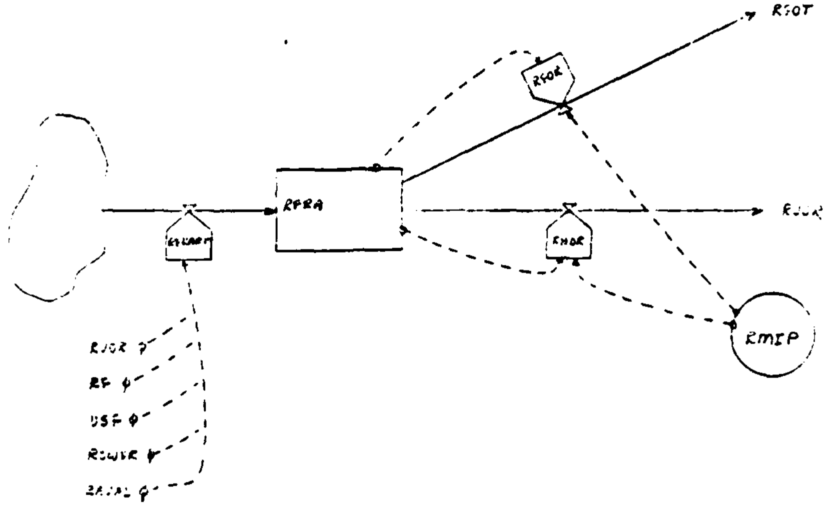


Figure 37. ROW Force Requests Processing Sector---
Flow Diagram

L RFRA.K(I1,I2) = RFRA.J(I1,I2) + DT * (RFRART.JK(I1,I2)
- RFOR.JK(I1,I2) - RFOR.JK(I1,I2))

R RFOR.KL(I1,I2) = RFRA.K(I1,I2) - MIN(RFRA.K(I1,I2),
RMIP.K(I1,I2))

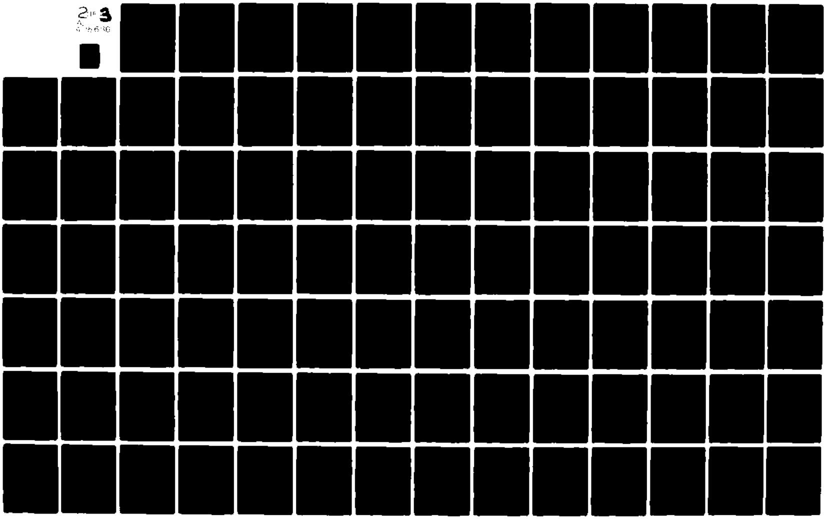
R RFOR.KL(I1,I2) = MIN(RFRA.K(I1,I2),RMIP.K(I1,I2))

A RMIP.K(I1,I2) = ROWCAP.K(I1,I2) * FPDROW(I2)

ROW Force Requests Approved (number of weapons). The level of ROW Force Requests Approved (RFRA) is determined by the ROW Force Requests Approval Rate (RFRART), ROW Foreign Ordering Rate (RFOR), and the ROW Home Ordering Rate (RHOR). From the equations it can be observed that RHOR is equal to RFRA or the maximum ROW force production capability which ever is smaller. The remaining RFRA, if any, are given to the ROW to fill. The Maximum ROW Force Production Capability (RMIP) is equal to the ROW Capital Inventory (ROWCAP) times the ROW Force Production Delay (FPDROW).

AD-A115 686 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOO--ETC F/G 5/3
A SYSTEM DYNAMICS APPROACH TO MODELING THE U.S. ARMS TRANSFER P--ETC(U)
MAR 82 M E NICKELL
UNCLASSIFIED AFIT/GST/OS/82M-10 NL

2 OF 3
AD
A115686



The next flow diagram and set of equations will be concerned with the division of ROW Foreign Orders (RFOT) rate orders sent to the US and those sent to the ROW, excluding home.

ROW Force Requests to the ROW Sector

The ROW Force Requests to the ROW Sector shown in Figure 38, is the continuation of the US Force Requests Processing Sectors shown in Figure 28. Approved ROW force requests that cannot be filled at home become ROW Foreign Orders (RFOT) which are then divided into orders sent to the US and those sent to the ROW. The division of orders is directly influenced by perceived US Hostility to the ROW (USHOST). The ROW orders sent to the US enter a queue and wait to be processed. Those orders which are sent to the ROW automatically become approved unfilled orders. This statement assumes that somewhere in the world there will be a country willing and able to sell the requested weapons system.

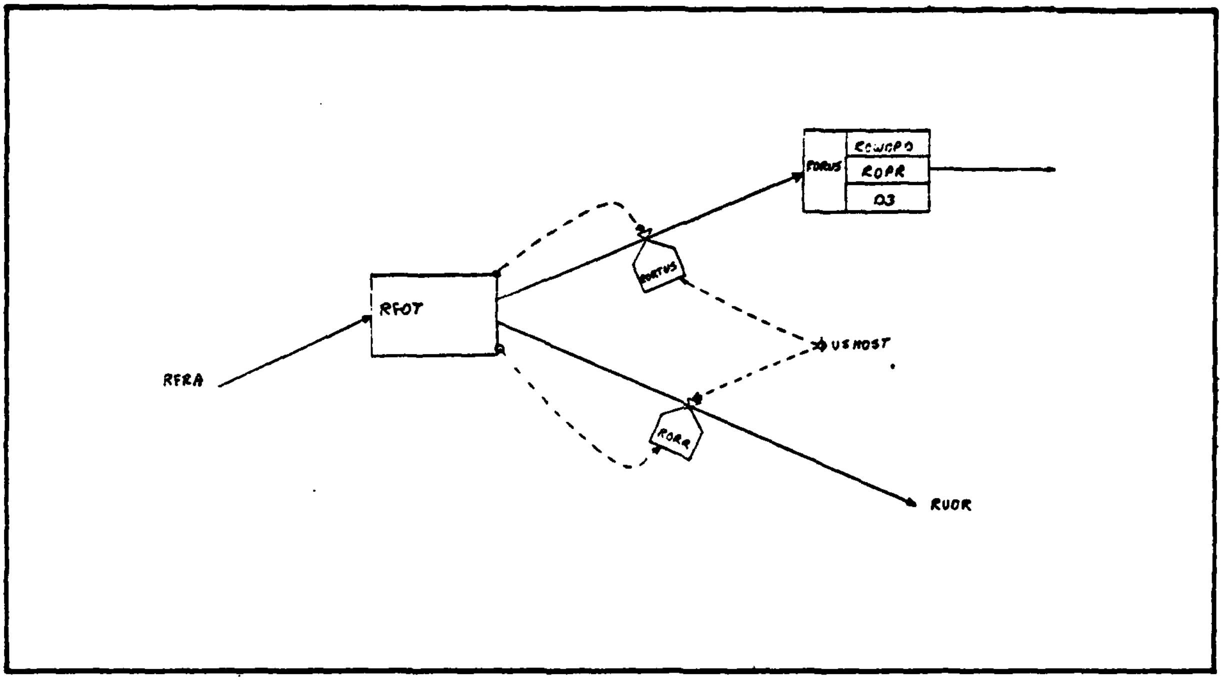


Figure 38. ROW Force Requests to the ROW Sector---
Flow Diagram

L RFOT.K(I1,I2) = RFOT.J(I1,I2) + DT * (RFOR.JK(I1,I2)
- RORTUS.JK(I1,I2) - RORR.JK(I1,I2))

R RORTUS.KL(I1,I2) = 1-USHOST(I1)) * RFOT.K(I1,I2)

R RORR.KL(I1,I2) = USHOST(I1) * RFOT.K(I1,I2)

ROW Foreign Orders Total (number of weapons). The level of ROW Foreign Orders Total (RFDT) is determined by the ROW Foreign Orders Rate (RFOR) minus ROW Orders to the US Rate (RORTUS) and ROW Orders to the ROW Rate (RORR). The orders sent to the ROW become ROW Unfilled Orders to the ROW (RUOR). The remaining orders which were sent to the US accumulate as ROW Orders to the US (RORUS).

L RORUS.K(I1,I2) = RORUS.J(I1,I2) + DT * (RORTUS.JK(I1,I2)
- ROPR.JK(I1,I2))

R ROPR.KL(I1,I2) = DELAY3(RDRUS.JK(I1,I2), ROWOPD)

ROW Orders to the US (number of weapons). The accumulation of ROW Orders to the US (RORUS) is determined by the ROW Orders to the US Rate (RORTUS) less ROW Orders Processed (ROPR). The rate at which the US processes ROW orders is described as a 3rd order delay. The length of the ROW Orders to the US Processing Delay (ROWOPD) is equal to half a year.

The next flow diagram and set of equations presents the processing of ROW orders to the US into approved or denied orders.

ROW Unfilled Orders to the ROW Sector

The ROW Unfilled Orders to the ROW sector is shown in Figure 39. After processing the ROW orders to the US are either approved or denied. Orders that are approved become ROW Unfilled Orders to the US (RUOUS) and the denied orders become ROW Unfilled Orders to the ROW (RUOR). The determining factors in what orders are approved or denied is US Inclination to Approve Orders (USI). As mentioned in the previous section, all ROW orders that are sent to the ROW will be filled. As industry produces the ROW requested arms the levels of US and ROW unfilled orders decrease.

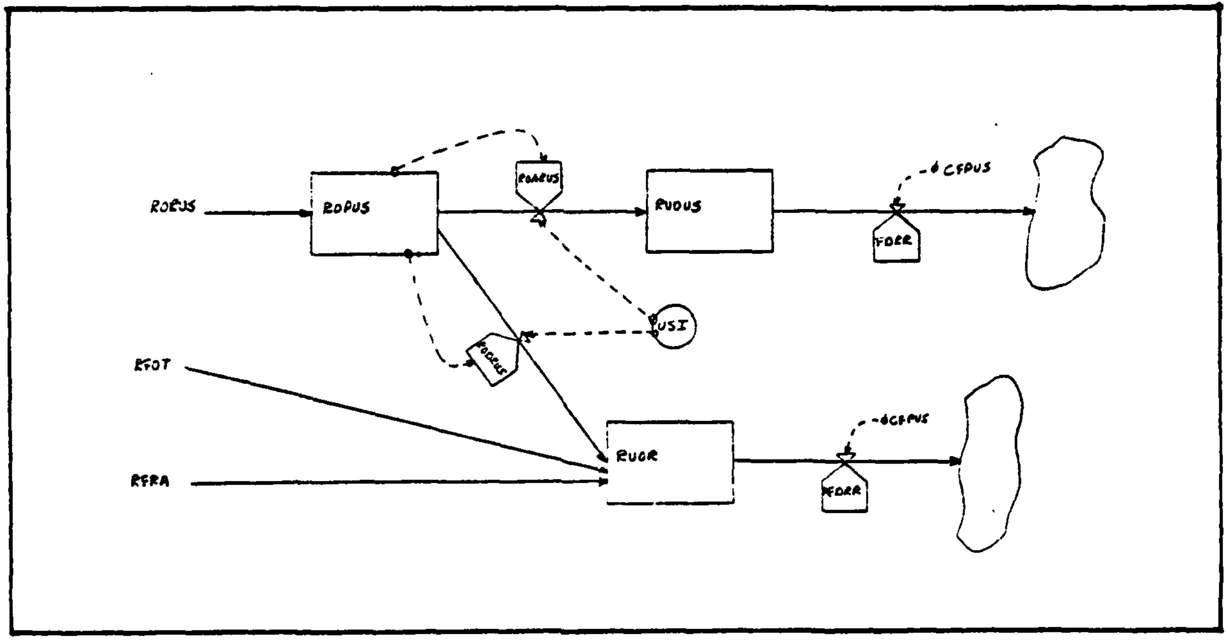


Figure 39. ROW Unfilled Orders to the ROW Sector---
Flow Diagram

L ROPUS.K(I1,I2) = ROPUS.S(I1,I1) + OT * (ROPR.JK(I1,I2)

= ROARUS.JK(I1,I2) - RODRUS.JK(I1,I2))

R ROARUS.KL(I1,I2) = ROPUS.K(I1,I2) * USI.K(I1,I2)

R RODRUS.KL(I1,I2) = ROPUS.K(I1,I2) * (1 - USI.K(I1,I2))

Processed ROW Orders to the US (number of weapons). The level of Processed ROW Orders to the US (ROPUS) is determined by the ROW Orders to US Processing Rate (ROPR), ROW Orders to the US Approval Rate (ROARUS) and the ROW Orders to the US Serial Rate (RODRUS). US Inclination to Approve Orders (USI) determines the number of ROW orders that will be approved or denied. The following equations define the accumulation of US and ROW unfilled orders from the ROW.

L RUOUS.K(I1,I2) = RUOUS.J(I1,I2) + DT * (RDARUS.JK(I1,I2)

- FDRR.JK(I1,I2))

L RUOR.K(I1,I2) = RUOR.J(I1,I2) + RODRUS.JK(I1,I2)

+ RORR.JK(I1,I2) - RODRUS.JK(I1,I2)

- RFDRR.JK(I1,I2))

R RFDRR.KL(I1,I2) = CFPR.K(I1,I2)

ROW Unfilled Orders to the US (number of weapons). The level of ROW Unfilled Orders to the US(RUOUS) is determined by the ROW Orders to the US Approval Rate (ROARUS), and the ROW Force Deployment Rate (FDRR) which equals the level of completed US force production for that particular country. ROW Unfilled Orders to the ROW (RUOR) is measured also in units of weapons ordered. From Figure 10, it can be seen that RUOR came from three sources, ROW home orders, ROW foreign orders to the ROW, and denied ROW orders to the US. As the ROW produces and deploys arms, RUOR decreases by a rate (RFDRR) which equals the ROW completed force production level.

The following flow diagram and equation set describes the ROW production cycle.

ROW Force Production Sector

The ROW Force Production sector shown in Figure 40 is very similar to the US Force Production Sector. In this sector, the level of ROW Forces in Production (FIPR) is determined by the ROW Planned Force Production Rate (PFPRR) less the ROW Force Completion rate (FPRR). ROW Completed Force Production (CFPR) is then deployed to the ROW at a rate equal to the level of CFPR. Forces deployed become part of the ROW Force Inventory (RF) which has a useful life span defined by ROW Force Life (ROWFL).

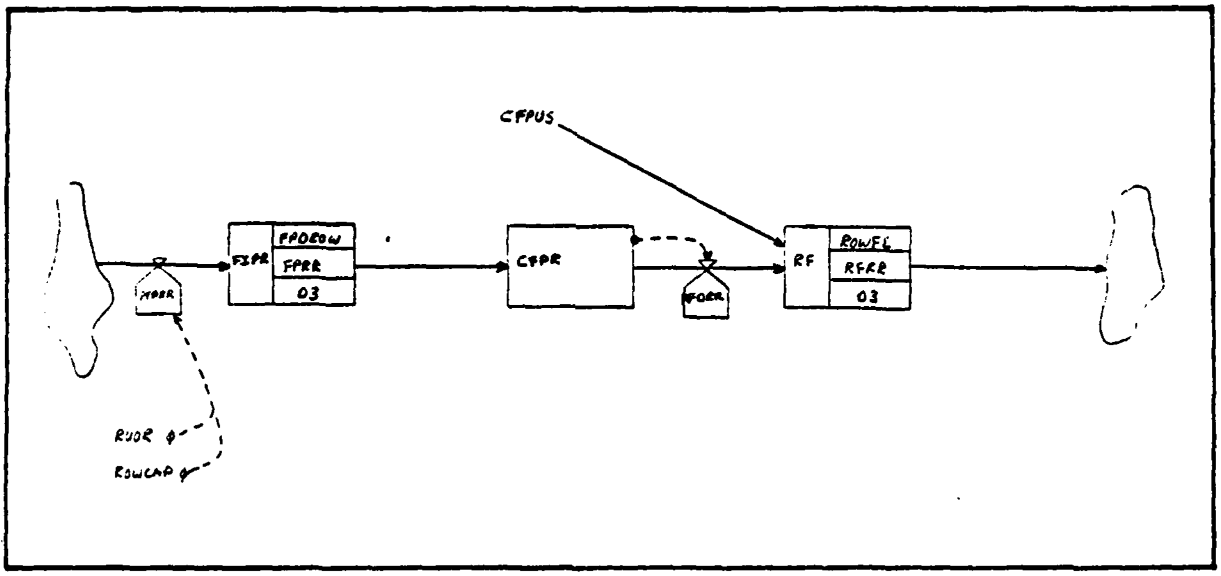


Figure 40. ROW Force Requests Production Sector--
Flow Diagram

R PFPRR.KL(I1,I2) = MIN(SUMV(ROWCAP(*,I2),1,NCNTRY) *
RUOR.K(I1,I2)/SUMV(RUOR.K(*,I2),1,
NCNTRY), RUOR.K(I1,I2))

ROW Planned Force Production Rate (weapons/period). The ROW Planned Force Production Rate (PFPRR) is equal to the fraction of each countries unfilled orders divided by the total ROW unfilled orders times the ROW Capital Inventory (ROWCAP). However, a limit is placed on PFPRR which implies that the ROW will not produce more orders than are requested.

R FIPR.K(I1,I2) = FIPR.J(I1,I2) + DT * (PFPRR.JK(I1,I2)
- FPRR.JK(I2,I2))

R FPRR.KL(I1,I2) = DELAY3(PFPRR.JK(I1,I2), FPDROW)

ROW Forces in Production (number of weapons). The level of ROW Forces in Production (FIPR) is determined by ROW planned Force Production Rate (PFPRR) and ROW Force Production Rate (FPRR). The rate of ROW force productions is depicted by a 3rd order delay over a time period equal to the ROW Force Production Delay (FPDROW).

L CFPR.K(I1,I2) = CFPR.J(I1,I2) + DT * (FPRR.JK(I1,I2) - RFDRR.JK(I1,I2))

R RFDRR.KL(I1,I2) = CFPR.K(I1,I2)

ROW Completed Force Production (number of weapons). The level of ROW Completed Force Production (CFPR) is determined by ROW Force Production Rate (FPRR) and ROW Force Deployment Rate (RFDRR). RFDRR determines the rate each countries completed force requests are deployed to their respective ROW Force Inventories (RF).

L RF.K(I1,I2) = RF.J(I1,I2) + DT * (FDRR.JK(I1,I2) + RFDRR.JK(I1,I2) - RFRR.JK(I1,I2))

R RFRR.KL(I1,I2) = DELAY3(FDRR.JK(I1,I2) + RFDRR.JK (I1,I2) , ROWFL(I2))

ROW Force Inventory (number of weapons). The level of ROW Force Inventory (RF) is determined by three rates. These rates include ROW Force Deployment Rate from the US (FDRR), OW Force Deployment Rate from the ROW (RFDRR), and the ROW Force Retirement Rate (RFRR). The rate that ROW forces retire can be described by a third order delay whose length is given by ROW Force Life (ROWFL).

The next sector will dsicuss the variables necessary to compute the amount of ROW funds available for defense appropriations.

ROW Funds Available Sector

The ROW Funds Available Sector is shown in Figure 41. This sector generates the ROW Funds Available (RAVAL) which is used to determine the ROW Force Requests Approval Rate (RFRART). As shown in the flow diagram RAVAL is a

complex variable that is influenced by economic conditions in the form of GNP, foreign relations as perceived hostility, and world unstability which is shown in the world arms requests. The following equations are used to calculate RAVAL.

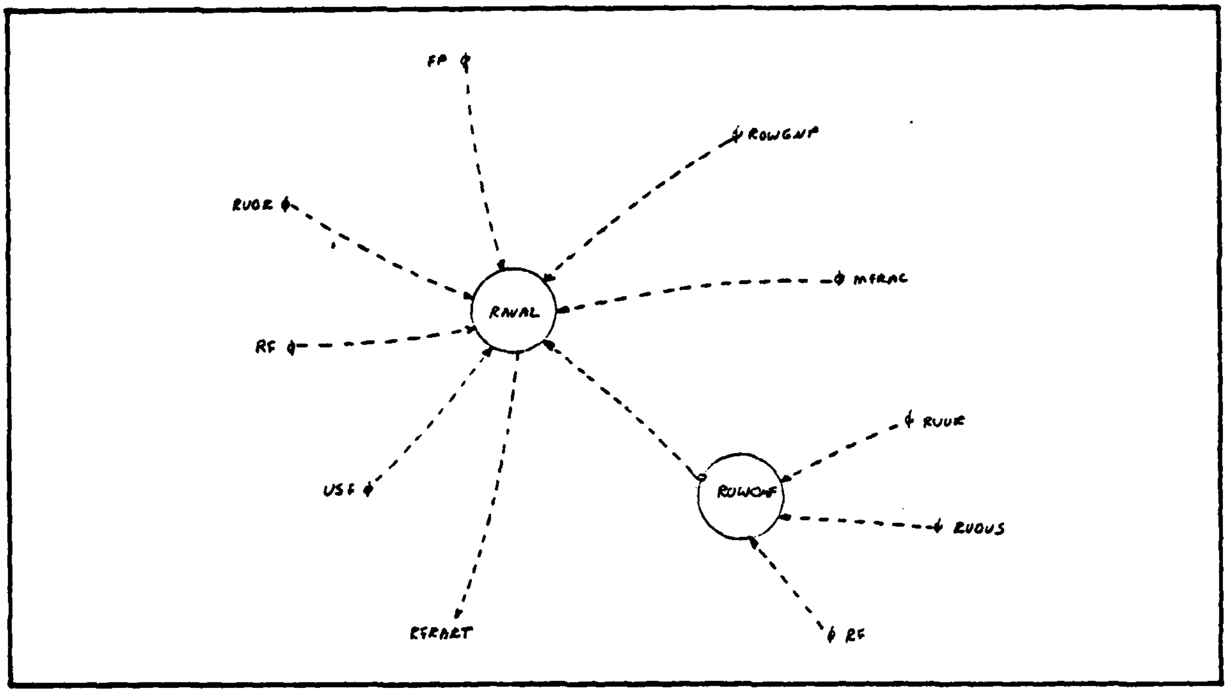


Figure 41. ROW Funds Available Sector---
Flow Diagram

A RAVAL.K(1) = ROWGNP(1) * MFRAC(1) - SUMV(ROWCMF.K(1,*),
1,3) - FP(1) * MIN(Ø,USF.K(1) * DNF6
- RF.K(1,1) - RUOR.K(1,1))

A RAVAL.K(I4) = ROWGNP(I4) * MFRAC(I4) - SUMV(ROWCMF.K
(I4,*),1,3)

A ROWCMF.K(I1,I2) = CMF(I2) * (RF.K(I1,I2) + RUOUS.K
(I1,I2) + RUOR.K(I1,I2))

Row Funds Available (millions of dollars). The first auxiliary equation for ROW Funds Available (RAVAL) is developed specifically for the Soviet Union. The reason is because the Soviet Union has no allies to help share the burden of developing and maintaining a nuclear inventory. The amount of funds the Soviets have available for defense appropriations is equal to the same portion of their GNP minus the cost of maintaining the force inventory minus the cost of purchasing new tactical nuclear weapons to maintain some desired nuclear level compared to the US. The second equation for RAVAL is equal to a portion of ROWGNP minus the ROW Cost of Maintaining Forces (ROWCMF).

The final flow diagram and set of equations describe the effects arms transfer have on US employment, GNP, and balance of trade.

US Employment, Gross National Product, and Balance of Trade Sector

The problem statement presented in Chapter 1 was concerned with the effects arms transfers had on the US economy, GNP, and balance of trade. Therefore, the purpose of this section shown in Figure 42, is to calculate these effects using variables that have been defined throughout the model. These equations are shown below.

A USRGNP.K = GNPF.K + USPIR.K + SUM(TFPIR.JK)

A USLF.K = LFF.K + (USPIR.JK + SUM(TFPIR.JK)) * EC

A EUSBT.K + SUM(TFPIR.JK) - SUM(CMFO.K)

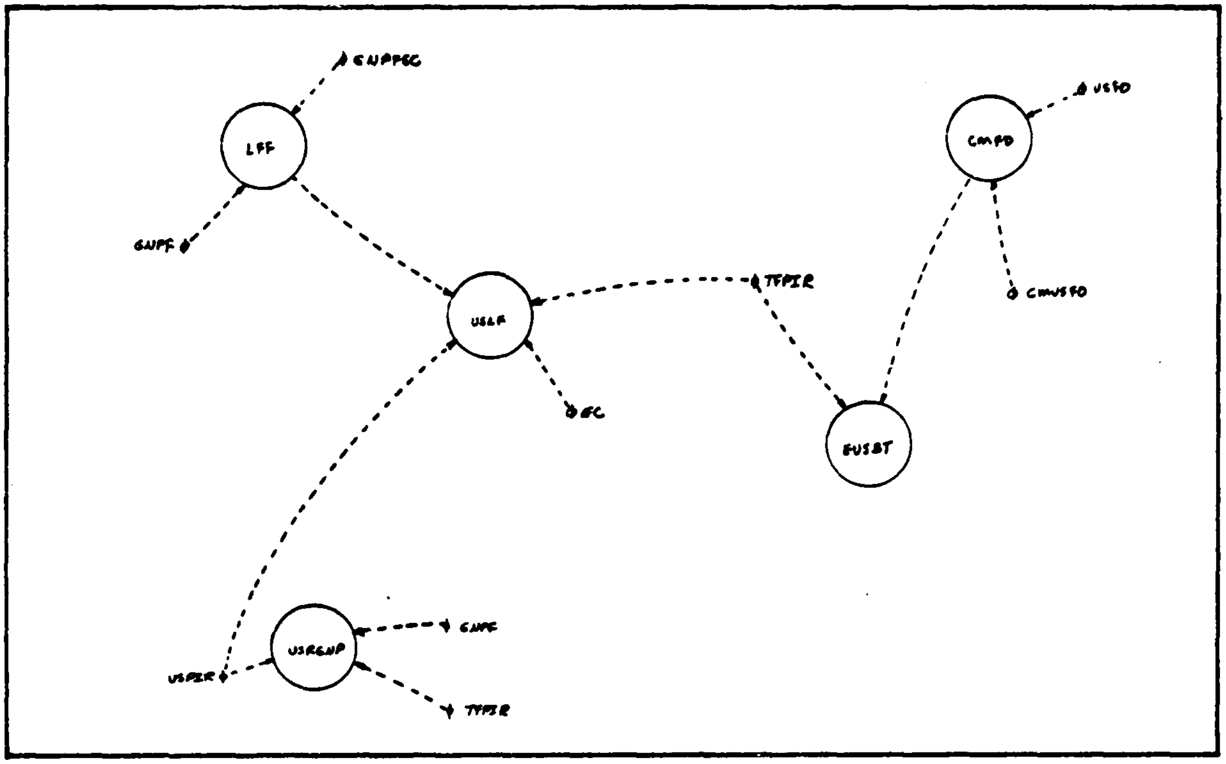


Figure 42. US Employment, Gross National Product, and Balance of Trade Sector---Flow Diagram

US Real GNP (dollars). In looking at US Real GNP (USRGNP) what is important is the effects that will be observed when different policy changes are made to the system such as invoking a ceiling on the dollars amount of FMS. From the equation it is seen that the variables influencing USRGNP are US Payment to US Defense Industry (USPIR) and Trust Fund Payment to US Defense Industry (TFPIR). US Labor Force (thousands of jobs). The US Labor Force (USLF) is the indicator that will be used to measure the effects FMS have on the US economy. USLF is affected by the Gross National Product Function (GNPF) which determines GNP in terms of 1972 constant dollars, USPIR, TFPIR, and an employment Constant (EC) which equals the number of people employed per 100 million dollars spent. Effect on the US Balance of Trade (EUSBT) equals the amount of funds received by the Trust Fund minus the cost of maintaining US forces overseas.

Summary

Chapters III and IV have discussed the development of the US Arms Transfer Model with the aid of causal-loop and system flow diagrams. The remainder of this report will be concerned with initiating model operation, testing model behaviour, evaluating model accuracy, and discussing the effects different policy decisions have on the model.

V. Verification and Validation

The purpose of this chapter is to check that the model is indeed performing as constructed and that it accurately reflects the system under consideration.

Verification vs Validation

Verification can be defined as insuring that the model is performing as designed and validation, that it accurately reflects the system in question. However, in practice the two processes become intermixed. While verification (which included debugging) usually lends itself to relatively concise, objective treatment, such as tracing model operations, validation is subjective and consists of comparing model performance to real-world data or experience. One aspect of testing that was not addressed in this study was the verification of the internal DYNAMO functions, such as the summing, random number generation, pulse, and other utility routines. They were assumed to operate as specified. Thus no attempt was made to directly verify the performance of the language itself. However, the performance of the model based on the perception of how it should run was addressed.

In a large sense, validation includes insuring that the

pieces which form the model, as well as the way in which these pieces are assembled, are sufficiently realistic to promote confidence in the final product. This process begins at the very earliest stages of conceptualization and continues through selection of model structure and methods, for testing various model components. Indeed, the process is almost an unconscious one and is an important part of decisions and assumptions affecting model development.

By building the model in stages (as was done in the arms transfer model) the task of verification and validation becomes easier, with each stage of development representing a continued growth of understanding about the system. Each stage can be verified and validated before continuing model construction. Once the final model has been assembled, the various components again need to be checked in the overall context. At all stages, the model output is compared to expect model behavior to insure the output is reasonable. However, when observing system processes one should be alert to counter intuitive behavior which may occur. As Forrester noted, "... a complex information feedback system designed by happenstance or in accordance with what may be intuitively obvious, will usually be unstable or ineffective (Ref 17:15)."

Therefore, a complex system such as the arms transfer process may produce other than expected results.

Discussed in the following sections will be the behavior of the system in an effort to add some validity to them model. This analysis of systems behavior will be done on a sector by sector bases as was done in Chapter III and IV.

The behavior of each sector will be presented using plots of systems variables over time. The variables being plotted are indicated at the top of the first page of each set of plots as shown in Figure 43. Also at the beginning of each set of plots will be the scaling scheme used for the plotted variables. Most plots will contain at least three variables, and often as many as six. This technique of multiple plots was used in an effort to enhance the discussion of the causal-relationships that exist in the system. The first sector that will be discussed will be concerned with the US force requests.

US Force Requests Sector

The first plot shown in Figure 43 contains the variables USFRRT (the rate at which the US requests forces), USFR (the number of accumulated force requests), and USFRPR (the rate at which US force requests are processed). As seen from

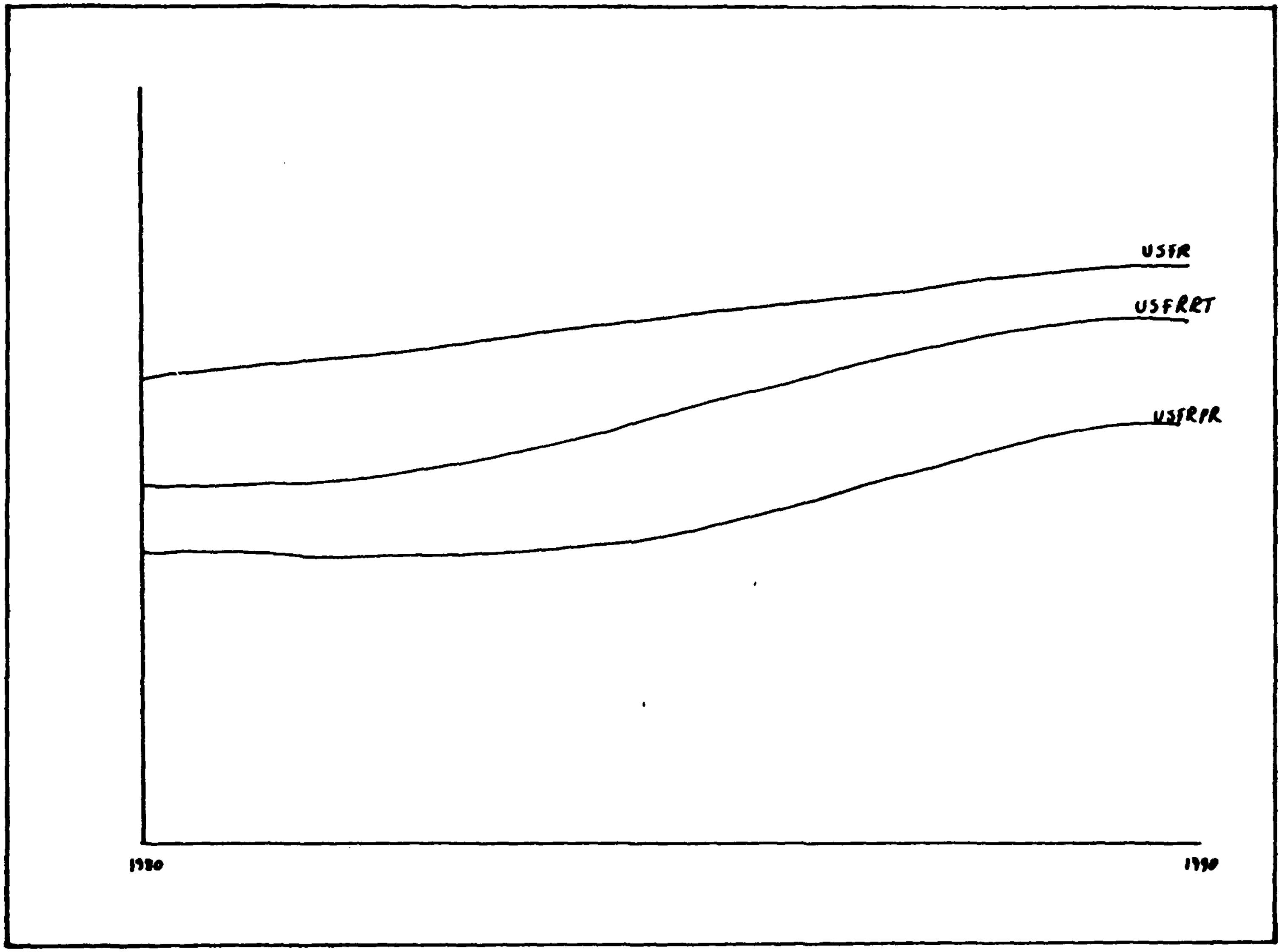


Figure 43. US Force Requests Sector - System Output Plot I

the plots, as USFRRT increases there is a corresponding increase in USFR which supports the information presented in Chapter III. The rate at which USFR's are processed (USFRPR) is equal to USFRRT delayed over 3/4 of a year.

Therefore as USFRRT increases, USFRPR will also increase but at a slower rate. However, if USFRRT starts to decrease then in time USFRPR may come to be larger than USFRRT. Also the delay placed on USFRPR will cause it to smooth out any sudden changes in force requests.

The next plot shown in Figure 44 contains the variables USFRP (the accumulation of processed US force requests), USFRAR (the rate at which US processed force requests are approved), USFRDR (the rate at which US force requests are denied), USPCFA (the pressure placed on Congress for force appropriations), USUO (the accumulation of US unfilled orders), and FDRTUS (the rate at which US forces are deployed after production). Illustrated in this plot is the rate at which US forces are approved (USFRAR) and denied (USFRDR). From Chapter IV it was stated that USPCFA would represent a percentage of forces that would be approved and therefore must have a value between zero and one. Figure 44 shows that USPCFA begins with a value of 70% and slowly increases which causes a corresponding increase in USFRAR and a decrease in USFRDR as was expected. As orders are denied

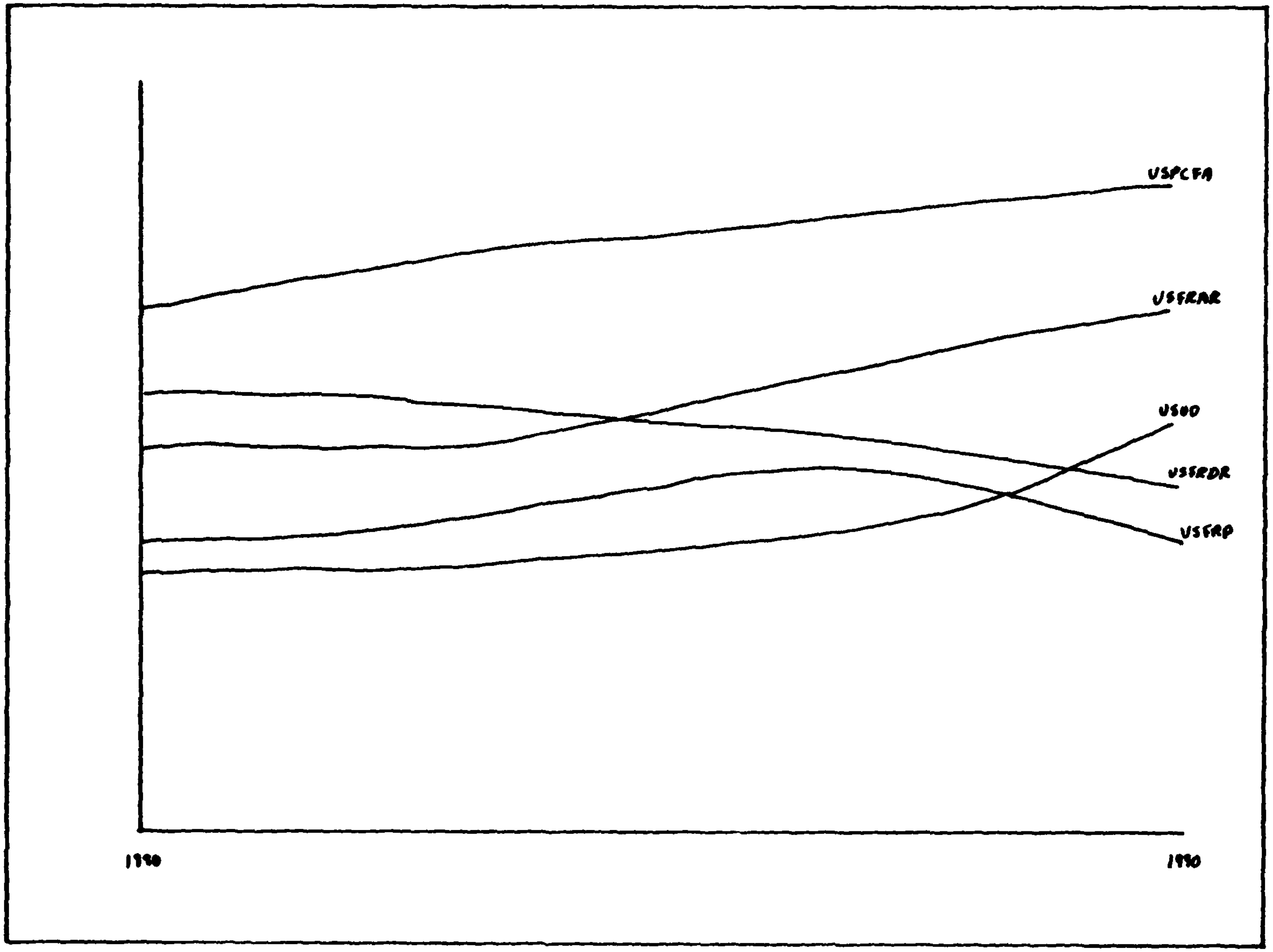


Figure 44. US Force Requests Sector - System Output Plot II

they are forced to leave the system, therefore lowering USFRP. The orders that are approved become US unfilled orders which are shown by the increase in USUO on Figure 44. The level of unfilled orders decreases when USFRAR is less than FDRTUS.

Therefore, based on these plots of the variables which are defined and calculated in the US Force Requests Sector, it appears the system is behaving as expected. The discussion of the next sector will be concerned with the affect different pressures have on Congresses willingness to appropriate funds for force requests.

US Pressure on Congress For Force Appropriations Sector

Shown in Figure 45 are six variables, five of which are used in calculating USPCFA (the result of pressure placed on Congress for force appropriations). These variables are RI (a regional instability indicator), CT (the sum of the total force size of the rest of the world (ROW) threat towards the US), ILP (the industry lobby pressure), USF (the size of the US force inventory), and USUO (the number of unfilled orders). USPCFA is a very important variable in the arms transfer model, because it directly determines what percentage of US force requests will be approved or denied. As mentioned in the previous sectors, USPCFA must remain at a value between zero and one which it does. USPCFA is also one of the most sensitive variables in the

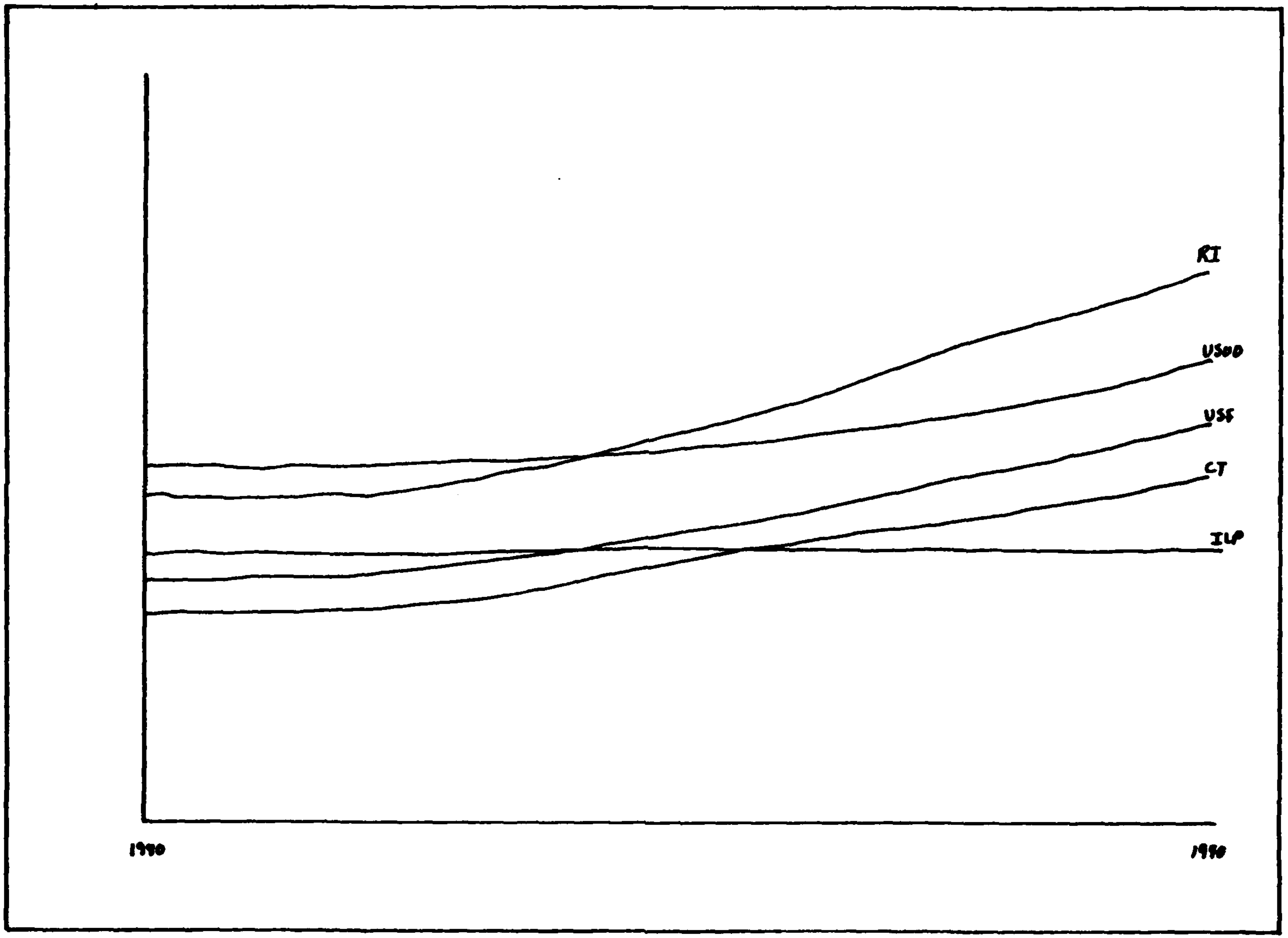


Figure 45. US Pressure on Congress For Force Appropriations - System Output Plot

model. This is due to the nature of the variables which are used to calculate it. In controling USPCFA several weighting constants are used to scale the effect CT, ILP, USUO, USF and RI have on USPCFA. The next plot figure will pertain to the US production cycle.

US Force Production Sector

Figure 46 contains the variables PFPRUS (the planned US force production rate), FIPUS (the forces in production in the US), FPRTUS (the actual vs production rate), and FPDUS (the length of the force production delay). The primary purpose of this plot is to emphasize the uncertainty associated with PFPRUS and to show its effects on FIPUS and FPRTUS. What is interesting is the difference between planned and actual force production where actual production lags behind planned force production as shown in Figure 46, which is consistent with what happens in the "real world."

Figure 47 contains the variables CFPUS (the completed US force production), FPRTUS (the force production rate for the US), FDRR (the force deployment rate of US produced forces by the ROW), and FDRTUS (the force deployment rate of US produced forces by the US). It is important to remember that in this sector the US is producing goods for both the US and the ROW. However, in the model, which does not necessarily reflect reality, the US has first priority on US produced arms. From Figure 47 it can be seen that FDRR

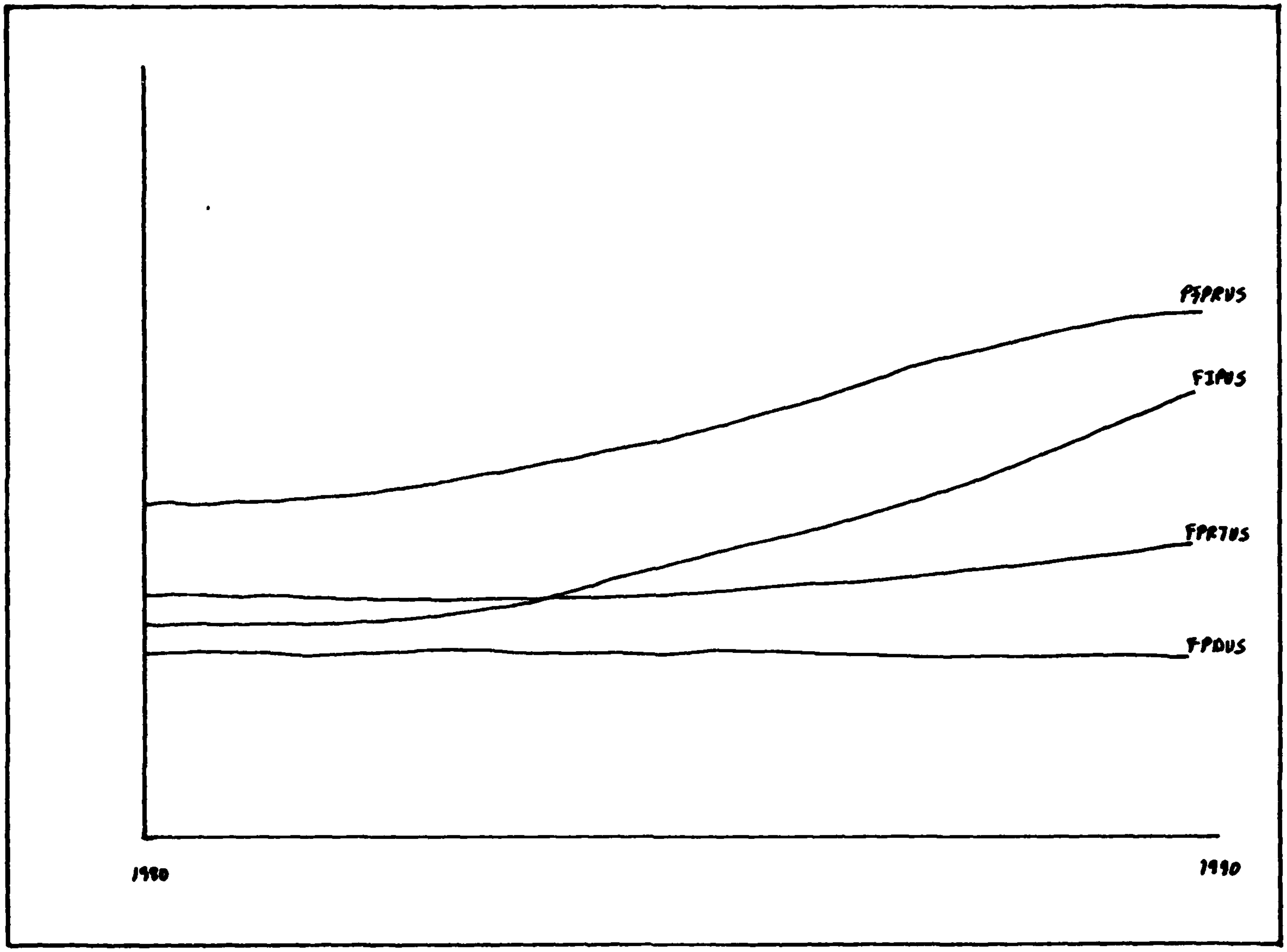


Figure 46. US Force Production Sector - System Output Plot I

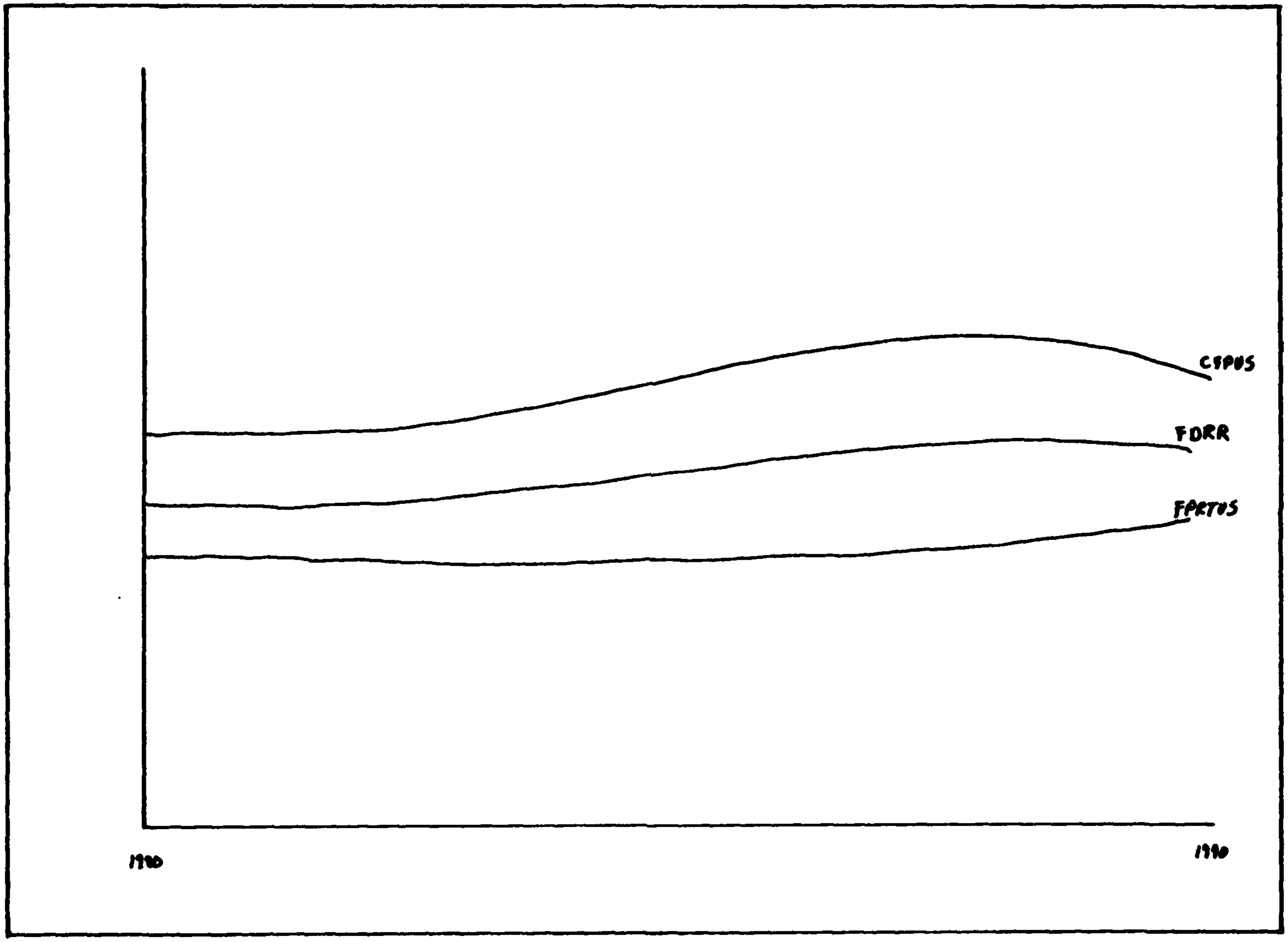


Figure 47. US Force Production Sector - System Output Plot II

equals CFPUS. This is because it is assumed that the purchasing country will want to take position of their goods as soon as possible. FDRTUS is also equal to CFPUS, however the level of forces completed for the US was not plotted so a comparison is not possible.

Figures 46 and 47 illustrate the interacting effects between the variables of this sector. The discussion of the following sector will be concerned with deployment of US forces overseas.

Deployment of US Forces Overseas Sector

The variables shown in Figure 48 which describe the deployment of US forces overseas are, USFC (the number of US forces in the continental United States), USFODR (the rate at which US forces are deployed overseas), USFO (the number of US forces stationed overseas), USOFRR (the rate at which US overseas forces wear out and are retired from the active inventory), and USFL (the life expectancy in years of US forces). This is an interesting sector in that it has a large influence on ROWFR (rest of world force requests) which will be discussed later. Also USFC is one of the major contributing factors to increasing the US trade deficit. From Figure 48, there appears to be a direct relationship between USFC and USFO. The model assumes that the US will always send some percentage of their new forces overseas due to force retirements (through age or use) and

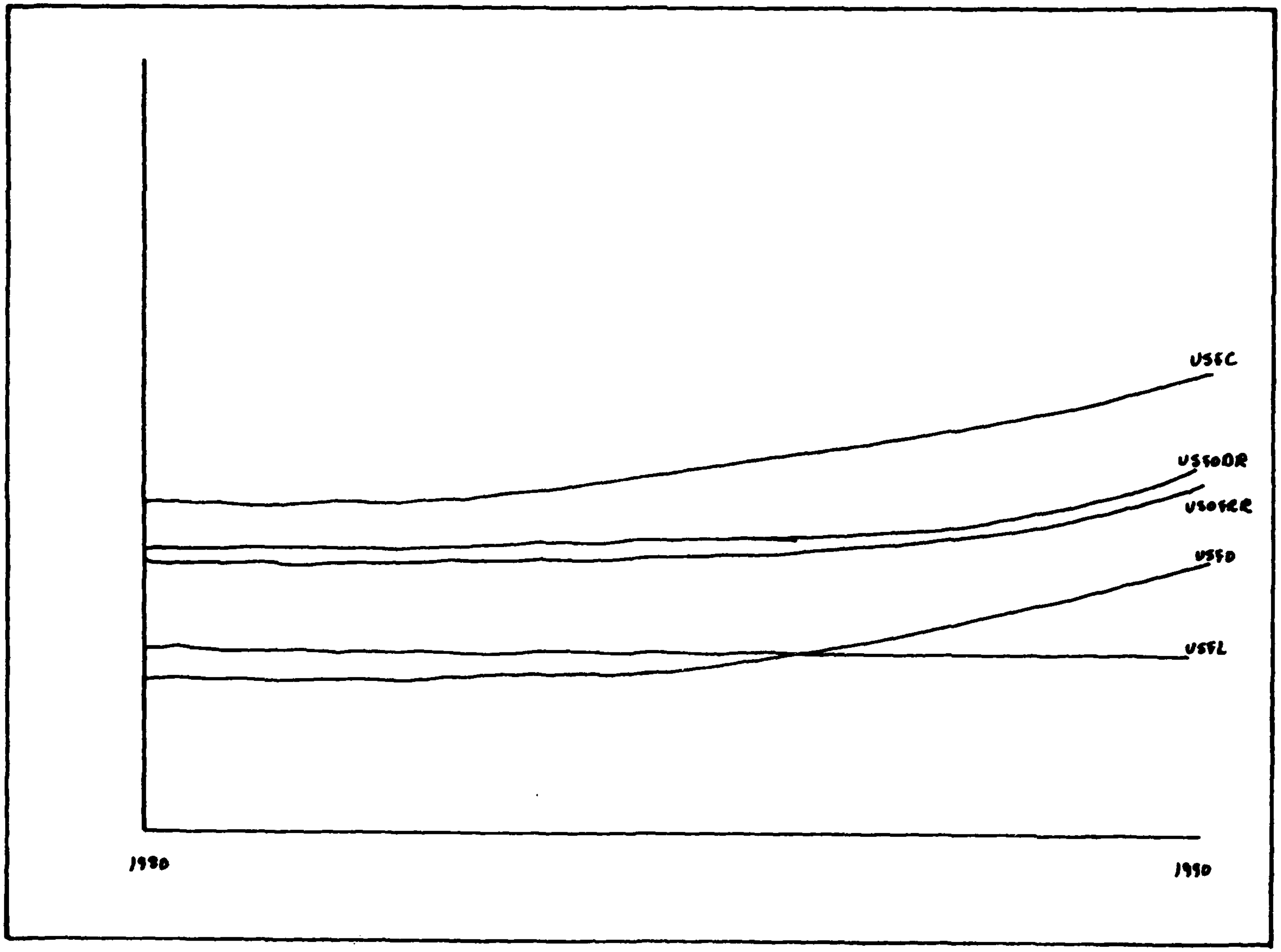


Figure 48. Deployment of US Forces Overseas Sector - System Output Plot I

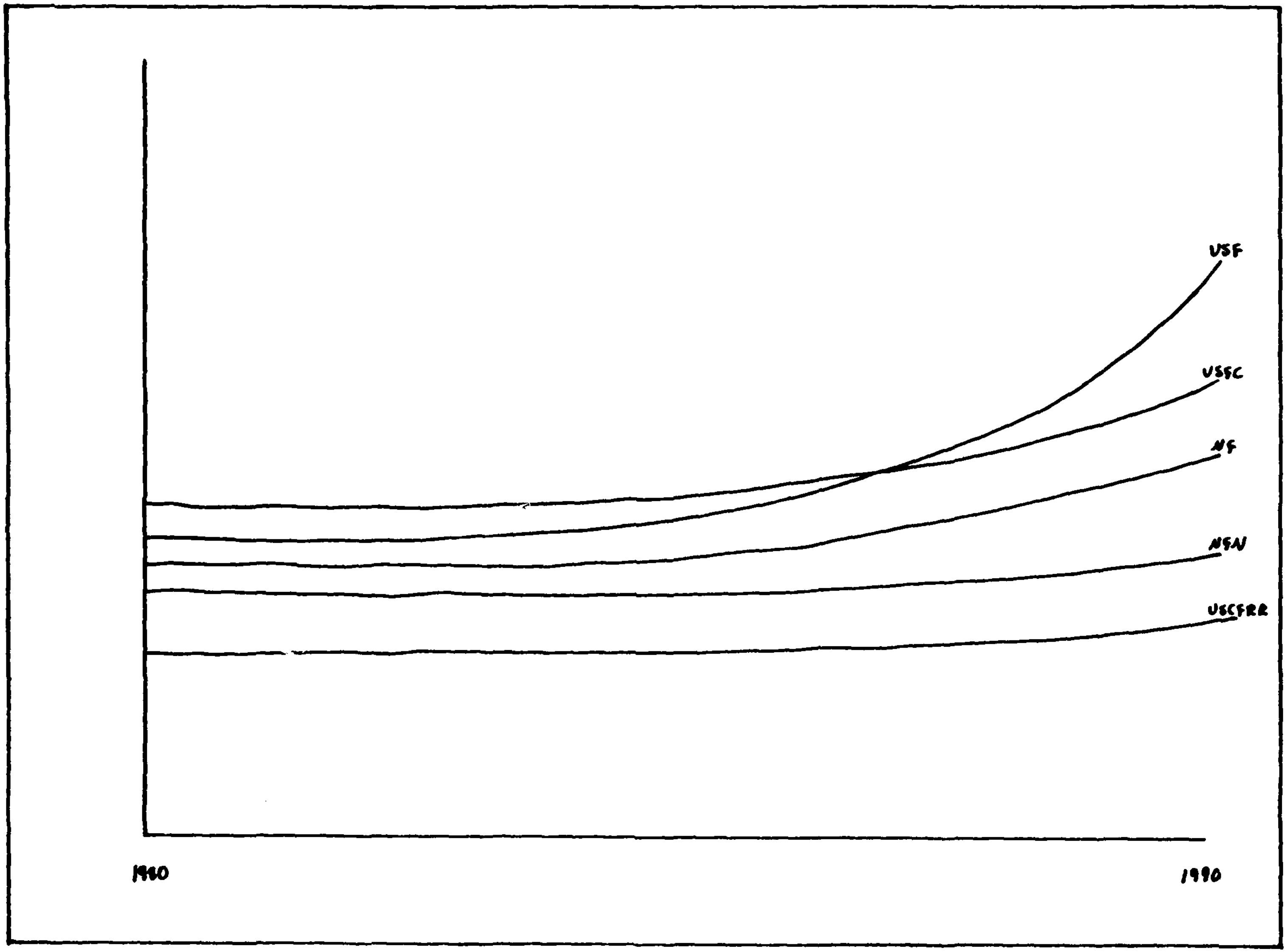


Figure 49. Deployment of US Forces Overseas Sector - System Output Plot II

perceived hostility in regions of importance to the US. What is not depicted on the plot is the policy decision of recalling US forces from overseas.

Contained in Figure 49 are additional variables which determine the level of US forces overseas. These variables include USFC (the number of US forces stationed overseas), USCFRR (the rate at which US CONUS forces are retired), NFN (the perceived threat from neighboring countries), NF (the size of neighboring countries force), and USF (the total size of the US force inventory). From Figure 49, it can be seen that all the curves have a positive slope. This is exemplified by the general trend which is occuring in the world today. Increased arms sales lead to an increase in perceived threat which results in more arms sales. This is a continuing growth spiral and is often refered to as "arms escalation." The next sector will be concerned with production of capital for the manufacturing of arms.

US Capital Production Sector

The plot shown in Figure 50 contains the following variables USPCPR (the planned capital production rate in the US), UO (the total number of US and ROW unfilled orders held by US industry), USCIP (the amount of US capital in production), USCAP (the total capital inventory of the US), and USCPR (the US capital production rate). Figure 50 shows that USCIP is directly related to USPCPR. This implies that as USPCPR

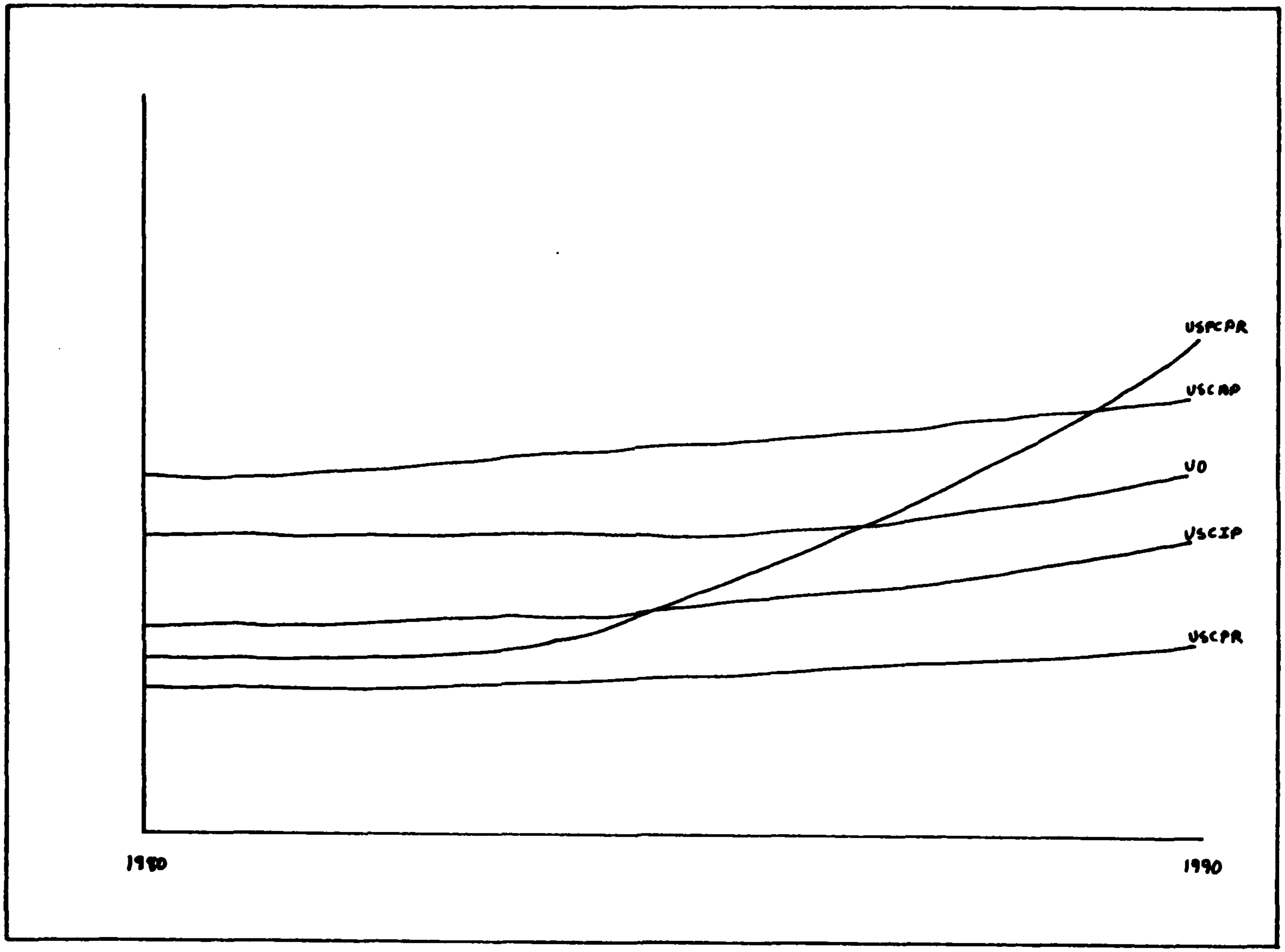


Figure 50. US Capital Production Sector - System Output Plot

increases so will USCIP. This example is seen in real life as the time that passes while waiting for an ordered good to be produced. Total capital inventory (USCAP) is another important variable in that it is one of few variables in the model that limits the continued growth of arms purchases. Discussed in the next sector will be the level of funds the US defense industry has available for continued business.

US Defense Industry Liquidity Sector

The variables shown in Figure 51 are PTFRT (the rate at which the ROW makes payment to the trust fund), TF (the level of funds in the trust fund), USART (the rate at which funds are made available to the US military), and USFA (the amount of US funds available for arms purchases). Because PTFRT is a function of the number of ROW unfilled orders then as ROW unfilled orders increase as shown in Figure 53 there will be an increase in PTFRT as shown in Figure 51. PTFRT is then used to determine the level of TF. The corresponding US variables are USART and USFA. The rate at which payments are made to the US defense industry are presented in the next figure.

Figure 52 contains the variables TFPIR (the rate at which the trust fund makes payments to defense contractors), USPIR (the rate at which the US government pays defense contractors), USDIL (the level of funds the US defense industry spends their available funds). The purpose of this

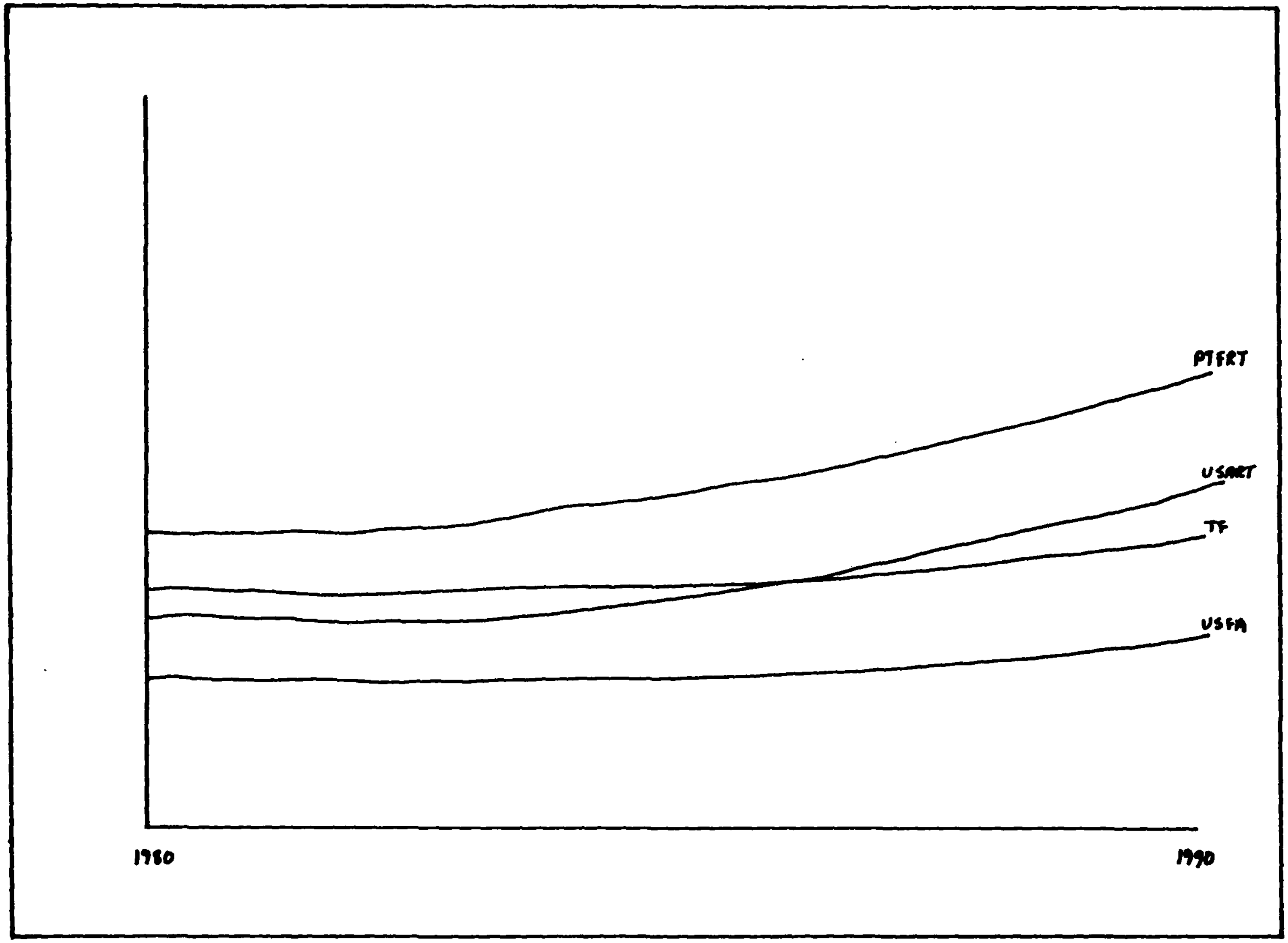


Figure 51. US Defense Industry Liquidity Sector - System Output Plot I

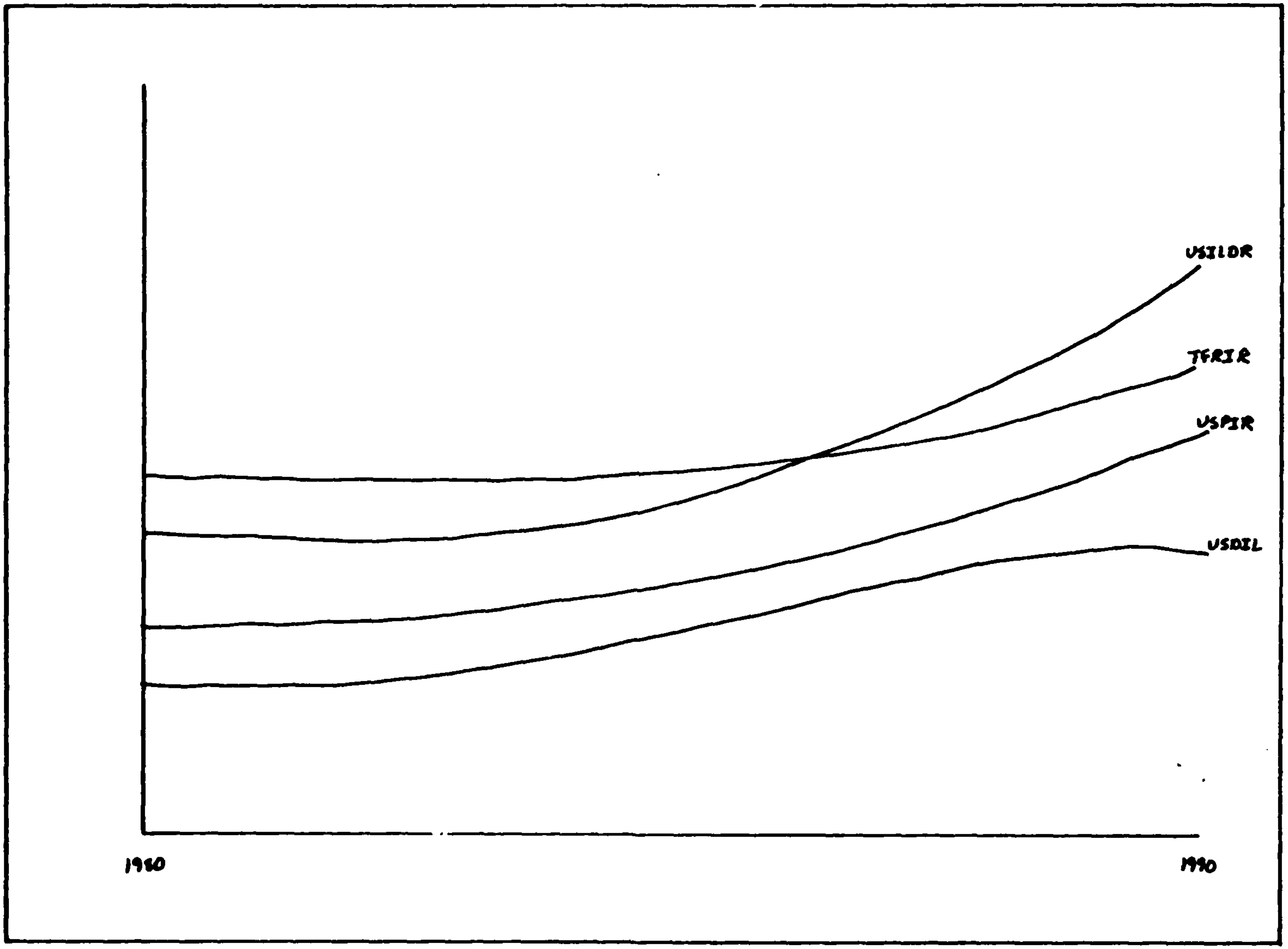


Figure 52. US Defense Industry Liquidity Sector - System Output Plot II

is to illustrate the payment of funds to the US defense industry and the effects that result. Figure 53 shows that as USPIR and TFRIR increase, there is a corresponding increase in USDIL. Also as USDIL increases the rate at which funds are released from USDIL also increases. Therefore, the change in USDIL will be determined by the difference between USILDR and USPIR plus TFPIR as is shown.

ROW Force Requests Sector

The plot for this sector, shown in Figure 53, contains five variables which are ROWFR (the number of ROW force requests), RFRA (the number of approved ROW force requests), RUOUS (the ROW unfilled orders held by the US), RUOR (the ROW unfilled orders held by the ROW), and USFO (the number of US forces overseas). The obtainment of an accurate representation for ROWFR is a very critical aspect of this model. Critical, because ROWFR is the variable that generates all ROW force requests including those to the US. From Figure 53 it can be seen that as RUOUS and RUOR begin to increase the number of ROWFR decrease. This is because once an order becomes an unfilled order, it is no longer considered to be a request. The effects that USFO have on ROWFR are mixed. The US has troops stationed in several countries throughout the world, most of which are friendly towards the US. However, the US does have troops stationed in unfriendly countries, an example of which is Cuba. Because of this

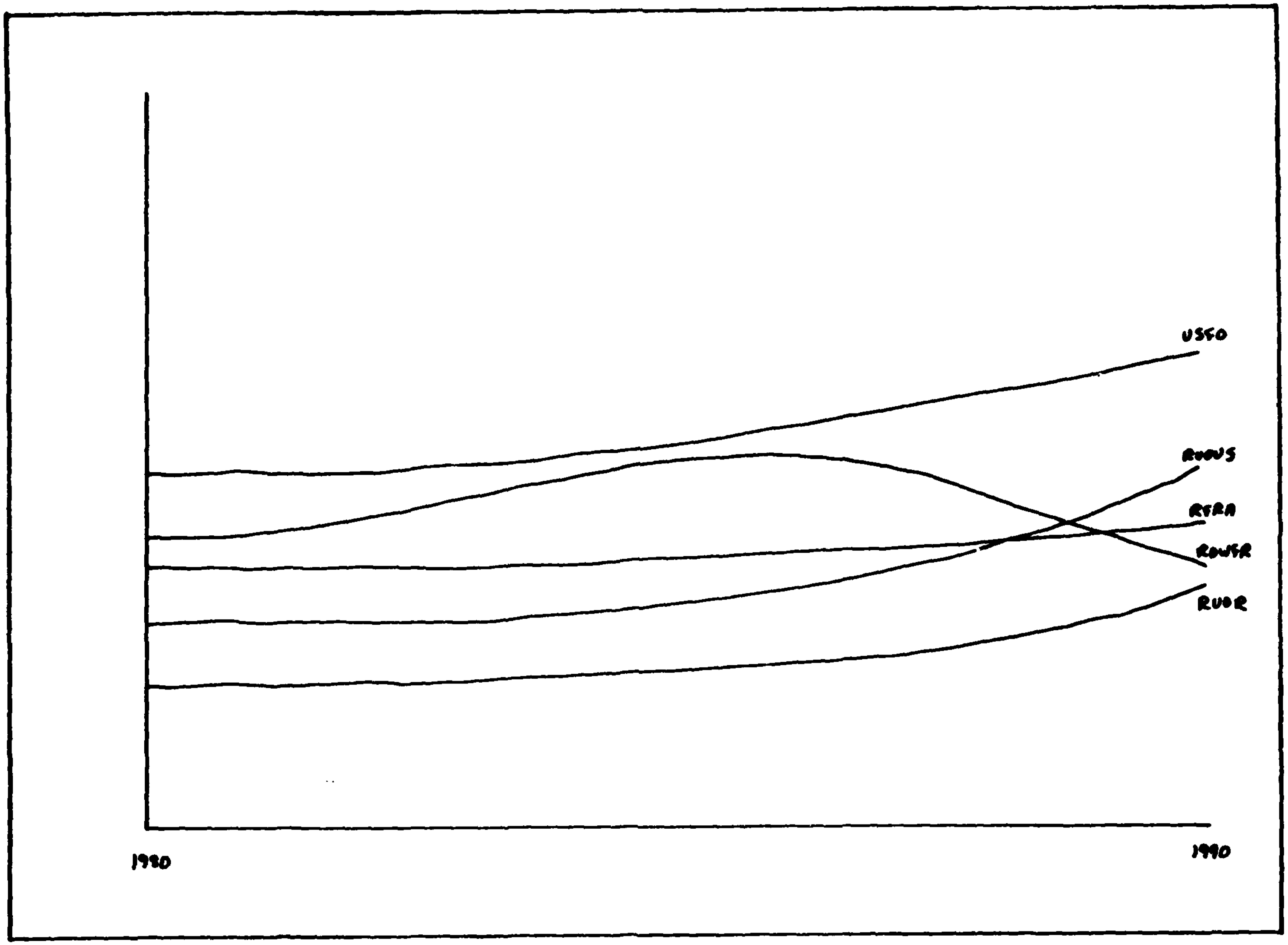


Figure 53. ROW Force Requests Sector - System Output Plot

particular problem, it was assumed that US troops would only be stationed in countries friendly to the US. Also implied, is that an inverse relationship with ROWFR exists because as USUO forces increase within a country, a corresponding decrease in ROWFR will result placing the burden of their defense on the US. These relationships are depicted in Figure 53. The next sector will consider the processing of ROW force requests.

ROW Force Requests Processing Sector

The variables of the US Force Requests Processing Sector, shown in Figure 54, are RFRART (the rate at which the ROW approves force requests), RFRA (the ROW approved force requests), RFOR (the rate at which the ROW generates orders for the ROW), RHOR (the ROW orders that are produced at home), and RMIP (the maximum amount of ROW force in production). The primary purpose of Figure 54 is to emphasize the relationship between RFRA and the rate variables RFRART, RFOR, and RHOR that influence it. An important issue is that RHOR is limited in the number of orders that can be produced at home, which is shown by the leveling of RHOR in Figure 54. This limit is due to RMIP which is directly related to the maximum ROW production capacity. Considered in the following sector will be the ROW force requests sent to the ROW.

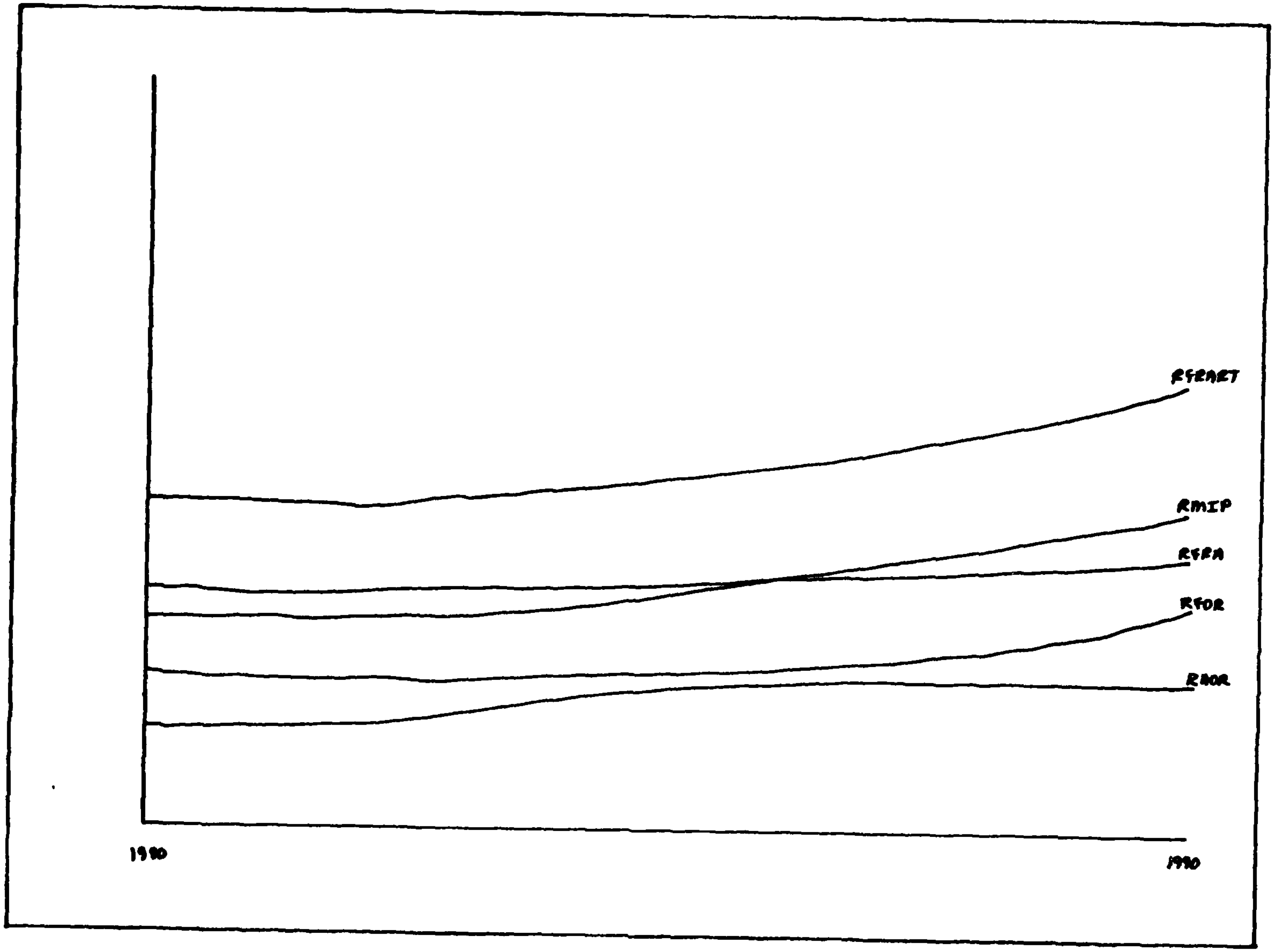


Figure 54. ROW Force Requests Processing Sector - System Output Plot

ROW Force Requests to the ROW Sector

Figure 55 contains the variables RFOT (the total ROW foreign orders), RFOR (the rate at which ROW foreign orders are generated), RORTUS (the ROW ordering rate to the US), and RORR (the ROW ordering rate to the ROW). Once ROW orders become foreign orders they are divided by RORTUS and RORR into orders sent to the US and those going to the ROW. By adding the two rate values together they equal RFOT which is expected because RORTUS and RORR are equal to a percentage of RFOT. This percentage is determined by USHOST which is the perceived US hostility towards the rest of the world.

Figure 56 considers the variables RORUS (the ROW orders received by the US), RORTUS, ROPR (the processing rate of ROW orders sent to the US), and ROWOPD (the delay involved in processing orders to be sent to the US). Figure 56 was included to illustrate the flow of orders from the ROW to the US. From Figure 56 it is obvious that as time passes this number of foreign orders continues to increase. This is a true reflection of what has taken place over the last ten years (Ref. 11).

Discussed in the following sector will be the concluding sector on processing ROW force requests.

ROW Unfilled Orders to the ROW Sector

The variables presented in Figure 57 are ROPUS (the accumulation of ROW orders to the US), ROPR (the rate at

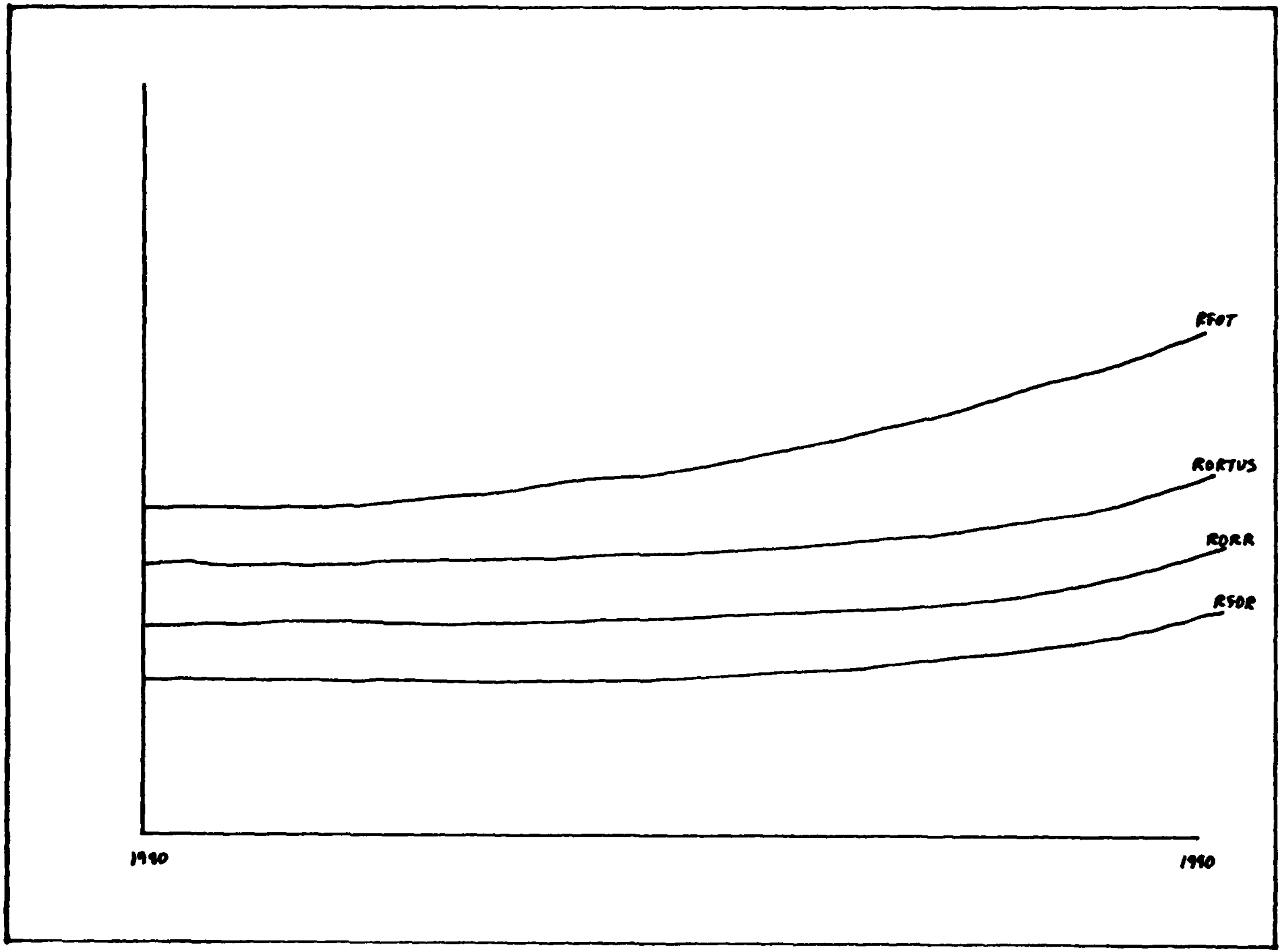


Figure 55. ROW Force Requests to the ROW Sector - System Output Plot I

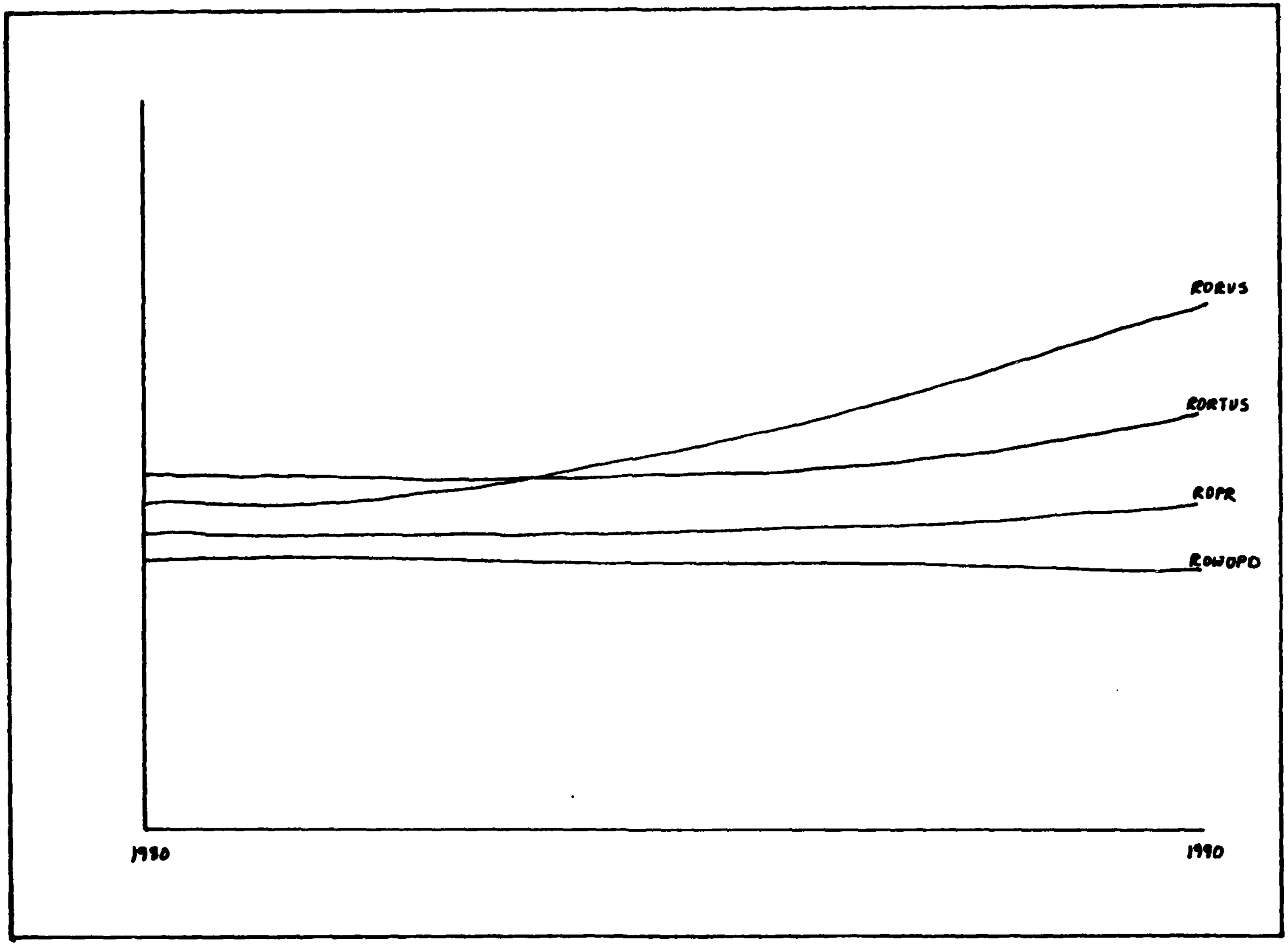


Figure 56. ROW Force Requests to the ROW Sector - System Output Plot II

which the US processes ROW orders), ROARUS (the rate at which ROW orders to the US are approved), and RODRUS (the rate at which ROW orders to the US are denied). The variables ROARUS and RODRUS are very important because they determine what happens to ROW orders sent to the US. By simple observation, it is seen that the sum of ROARUS and RODRUS are equal to ROPUS. The determining factor which is described in Chapter IV is USI (the US inclination to approve ROW orders). Hence, USI represents that percentage of ROW orders that will be approved. USI is a very sensitive variable and is shown to be a relatively slow changing curve whose values must lie between zero and one.

Figure 58 contains the variables RUOR (the number of ROW orders held by the ROW), RUOUS (the number of ROW orders held by the ROW), and RFRA (the ROW force requests approved). The purpose of Figure 58 is two fold. First, it shows that the sum of RUOUS and RUOR are equal to RFRA which is as expected. Also suggested here is that all orders denied by the US will immediately become approved ROW orders. This statement is based on a previously stated assumption that all ROW buyers will be able to find a willing and able supplier.

The figures of the last three sectors represents the ROW processing of force requests into US and ROW unfilled orders. Close examination of these figures and the associated flow diagrams and DYNAMO computer will provide the reader with an

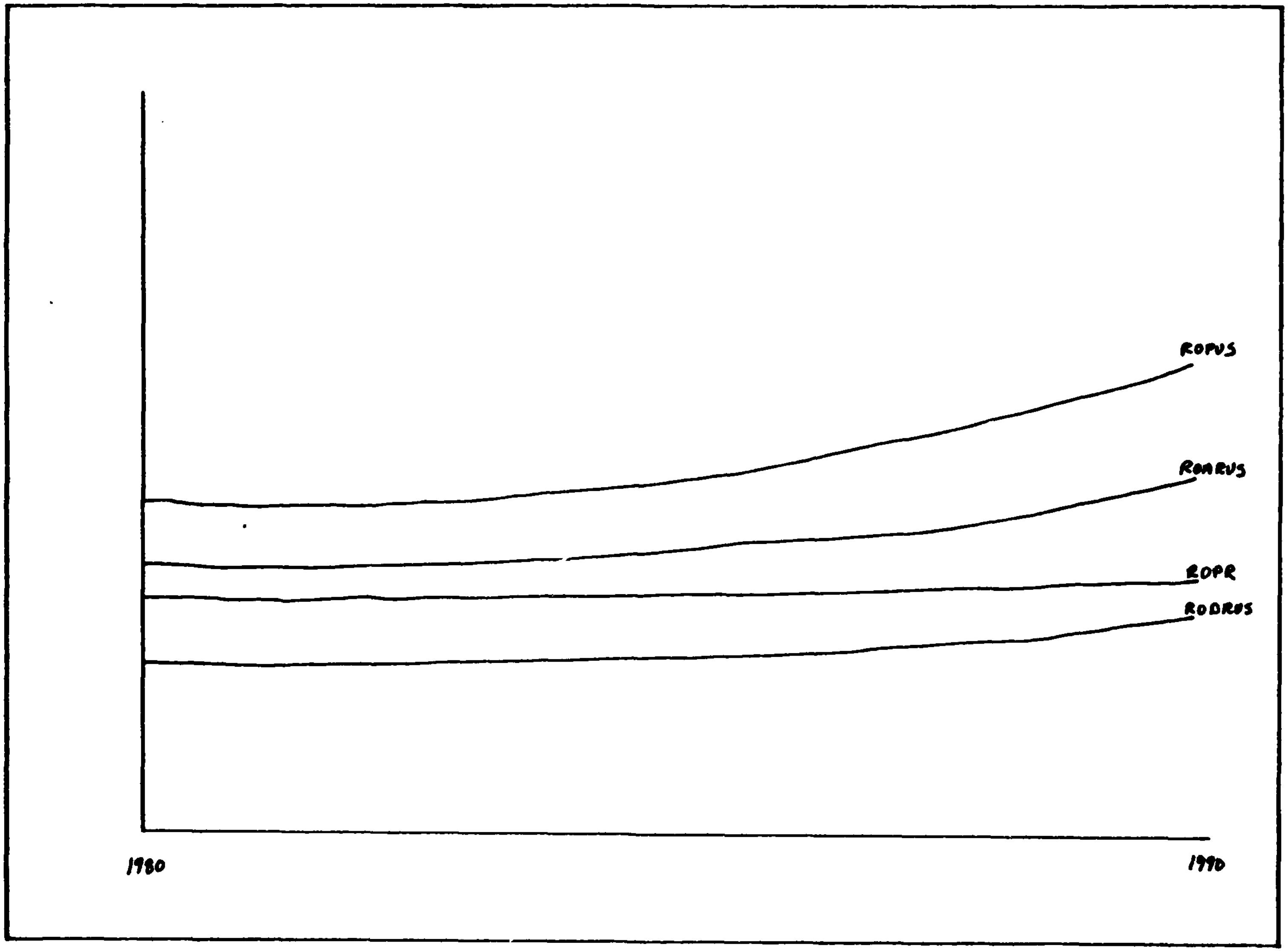


Figure 57. ROW Unfilled Orders to the ROW Sector - System Output Plot I

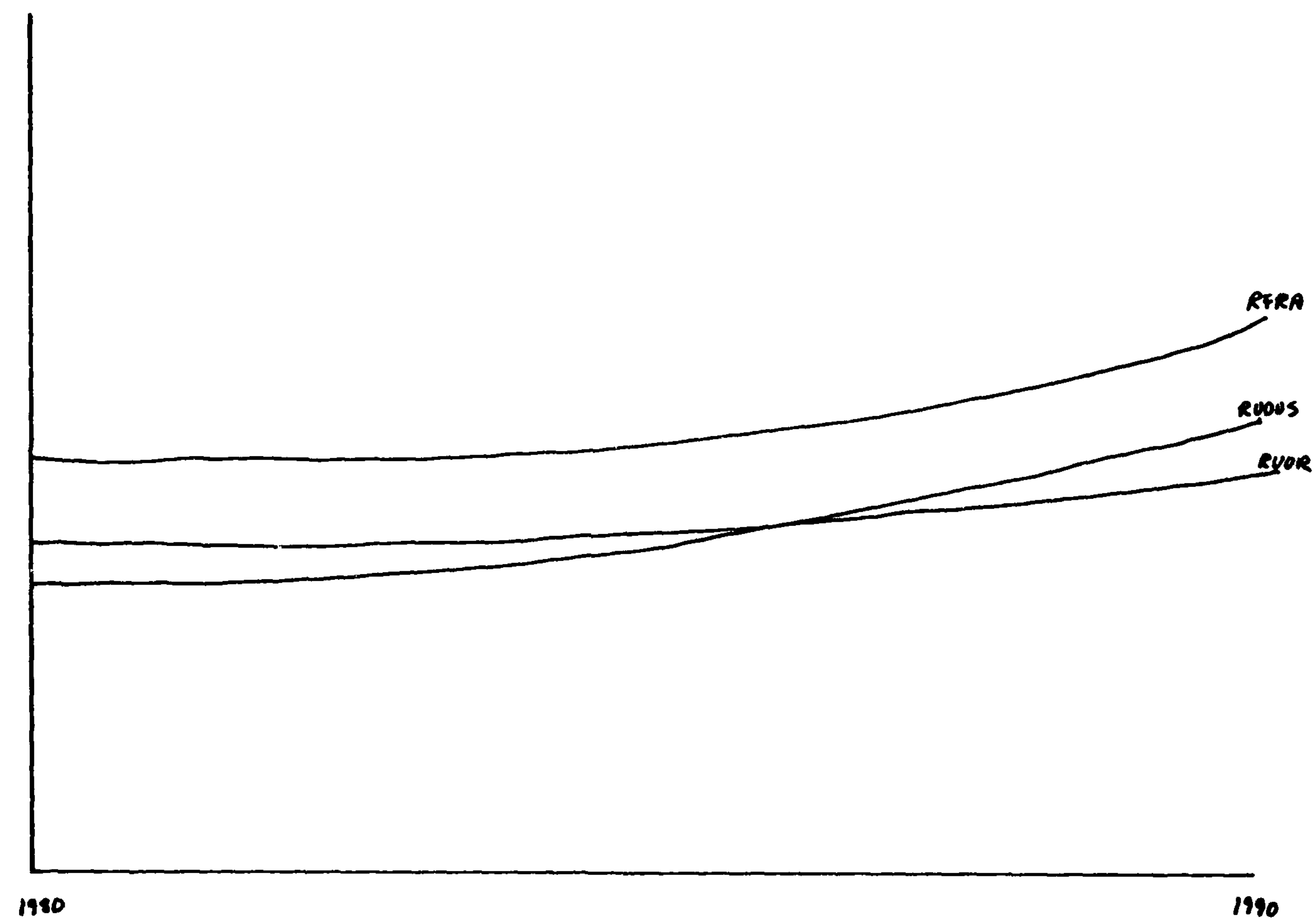


Figure 58. ROW Unfilled Orders to the ROW Sector - System Output Plot II

excellent understanding of this process. The next sector will be concerned with ROW force production.

ROW Force Production Sector

The variables shown in Figure 59 are PFPRR (the ROW planned force production rate), RUOR (the ROW unfilled orders held by the ROW), FPRR (the actual ROW force production rate), RF (the size of the ROW force inventory), and RFRR (the retirement rate of the ROW force inventory). From Figure 59 it can be seen that PFPRR is directly related to RUOR. Therefore as RUOR increases PFPRR will also increase. Also shown in Figure 59, RF continues to increase over the period of observation. This corresponds with reality in that the force inventories of the ROW have steadily increased over the past ten years. The next sector to be discussed will be concerned with the funds the ROW has available for arms purchases.

ROW Funds Available Sector

The variables shown in Figure 60 are RAVAL (the ROW available funds for arms purchases), ROWGNP (the ROW gross national product level), MFRAC (the military fraction of ROWGNP), and ROWCMF (the cost of maintaining current ROW force inventories). Figure 60 was included because it illustrates the steady increase in funds made available for arms

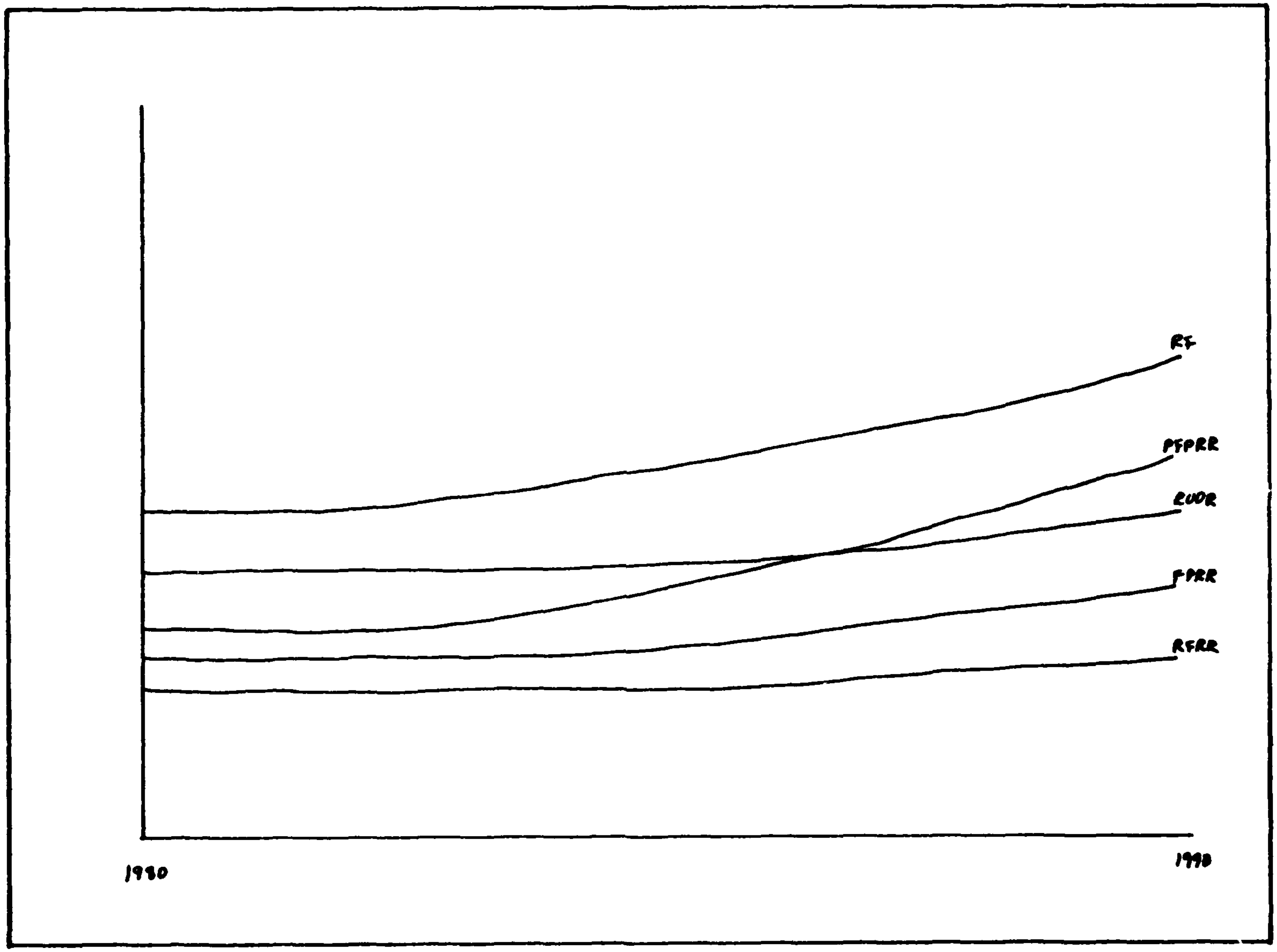


Figure 59. ROW Force Production Sector - System Output Plot

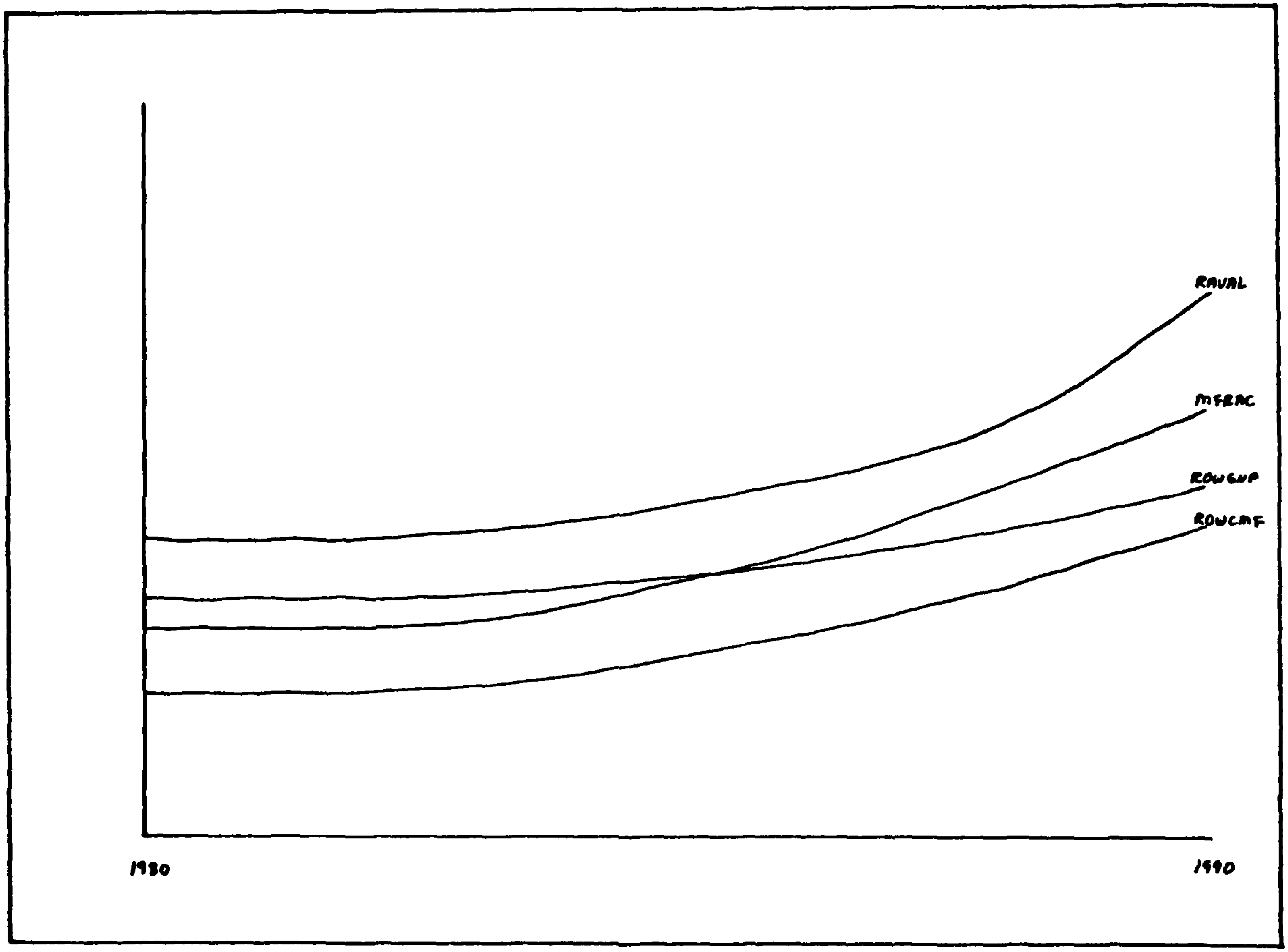


Figure 60. ROW Funds Available Sector - System Output Plot

purchases within the model which reflects the real world trends of the last ten years. Discussed in the final sector will be the effects of FMS on US employment, gross national product (GNP), US balance of trade, and world unstability.

US Employment, Gross National Product, and Balance of Trade Sector

The variables shown in Figure 61 are USRGNP (the changes on GNP due to FMS), USLF (the effect on the US labor force due to FMS), EUSBT (the effect of FMS on the US balance of trade), and ROWFR (the ROW force requests). The purpose of Figure 61 is to provide in one picture the desired results of the simulation model. USRGNP is calculated from the US and ROW payments to the US defense industry. USLF is computed by this change in GNP times an employment constant. EUSBT is computed by subtracting the cost of maintaining US forces overseas from monies received from ROW arms purchases. ROWFR which is computed from several variables is used as an indication of regional stability. From Figure 61, it can be seen that FMS do have a positive effect on GNP, USLF, EUSBT, and ROWFR. However, this positive effect on ROWFR implies that this particular region (NATO) is unstable.

With continued study, the interaction of the model variables with one another will become apparent. To try to understand the processes involved within this model is

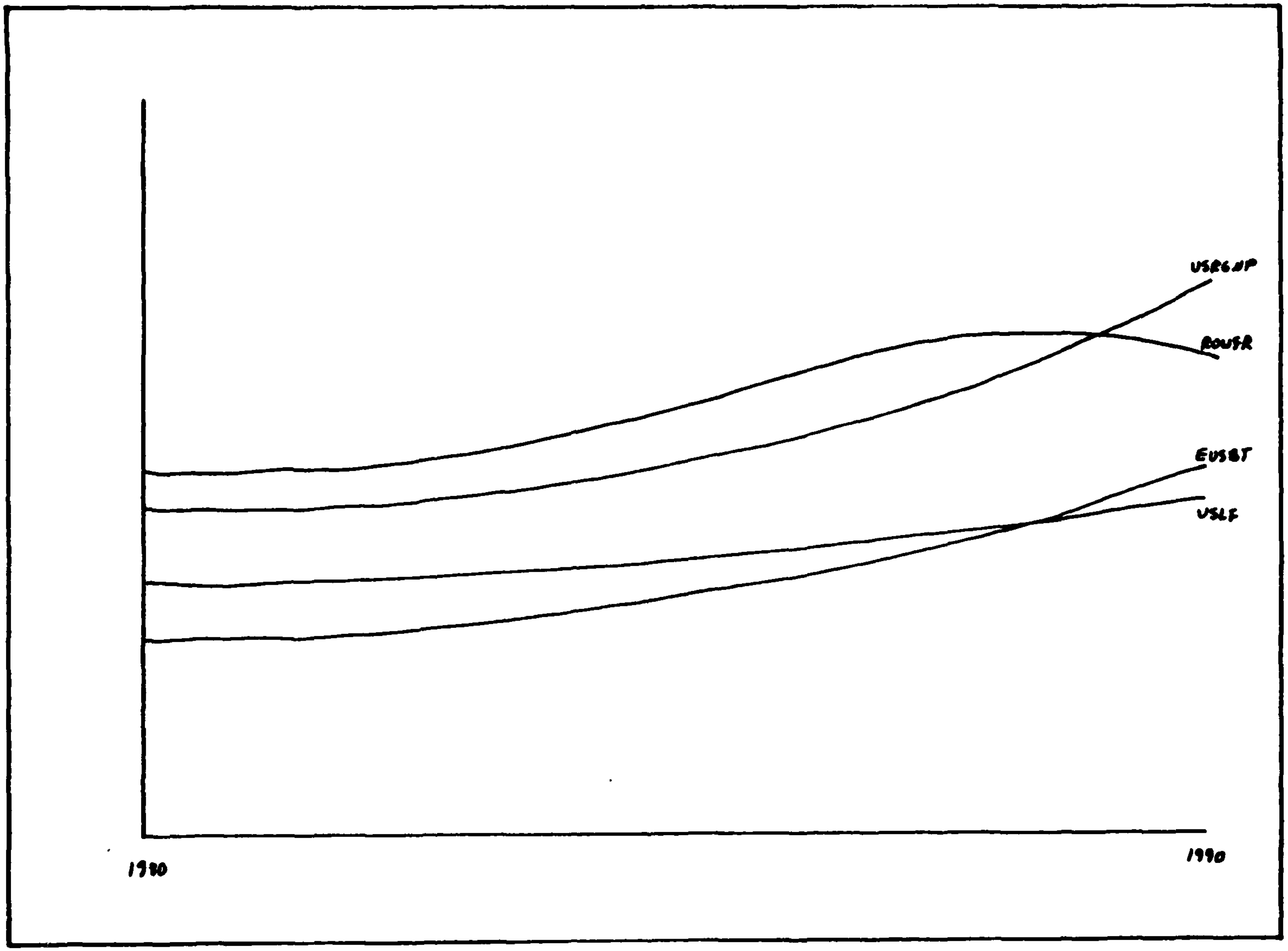


Figure 61. US Employment, Gross National Product, and Balance of Trade Sector - System Output Plot

not an easy task.

To truely understand the model the reader will need to concentrate on the model in terms of how it was developed.

Summary

Overall, the process of verification and validation traveled was as thorough as possible for a model of this type and complexity. Most important, was that each continued phase of development was based on what had to be learned previously which allowed a basis for later comparison of results. Therefore, the author is reasonably certain that the final model realistically represents at least the nature of the interaction within the arms transfer process. The next chapter will show how the finished model was used to analyze the effects of specific policy decisions concerning foreign military sales.

VI. Effects of Change

Introduction

> When the manager had achieved a viable understanding and began to manipulate the model, he continuously gained new insights into his operation (Ref 18:12).

These words of McKenny as told by Shannon highlight the purpose of this chapter. As the model developed so did the level of understanding. By manipulating the model even greater understanding and insights were obtained. The purpose of this chapter is to introduce policy and parameter changes into the system to observe their effects on model behavior.

However, before starting this analysis it is important to note that a complete analysis of the arms transfer process was not possible due to the time that would have been required. It is also not the purpose of this thesis to conduct an exhaustive examination of all variables that will effect the model. Rather, a limited analysis will be conducted for a representative feel for the model and to gain some insight into the system's performance. This will serve to demonstrate the use of the model for analysis and to provide the groundwork for further, more exhaustive research. Discussed in the remainder of the chapter will be the experiments performed using the model.

Experiments

For the initial experiment, the level of ROW unfilled orders held by the US (RUOUS) was reduced to zero. This was done in an effort to observe the affects this policy change would have on US employment, balance of trade, and gross national product. These effects are illustrated by the plots that make up Figure 62. Also contained in Figure 62 are the effects that resulted to the ROW from this reduction in US foreign military sales. The reduction of RUOUS was done by not accepting any new orders from the ROW for arms purchases form the US. Those orders that had already been accepted by the US were filled as the orders were produced. This decision of not accepting any new ROW orders would result from a policy change by the US Government. This change could result from one of several possible events. One reason might be that the US for some reason (possible war) may need all the arms it can produce for themselves. Another reason might be strict control of the world wide sale of arms.

This restriction of RUOUS began in 1982 (two years into the simulation run) and concluded in 1984 when it is assumed the restriction is lifted. A discussion of the major insights gained as a result of this experiment is in order.

To initiate the US's refusal to accept any new orders, USI (the US's inclination to approve ROW force requests) was reduced to zero in 1982 by using the DYNAMO STEP function.

This sudden decrease can be seen in Figure 62. Because of the time delays involved in the processing and production of arms requests, no immediate effects are seen in RUOUS, USRGNP (the US gross national product), USLF (the change in the US labor force), and EUSBT (the effect on the US balance of trade). However, as RUOUS decreased this lead to a decrease in the number of arms being produced which in turn corresponds to the decrease in the level of US employment. Also as the production of US arms decreased there was also a decrease in the levels of USRGNP and EUSBT. The levels of USRGNP, USLF, and EUSBT continued to decrease until in 1984 when the US resumed its acceptance of ROW force requests. Again because of the delay involved in processing orders the affect of the 1984 policy decision is not immediately seen in the generation of ROW unfilled orders (RUOUS). However, as ROW orders begin to be produced again, the effects on the decreasing trend in USRGNP, USLF, and EUSBT are apparent. Figure 62 shows that as production increases, so does employment (USFL). Also shown is that as arms are produced the payments to the TF resume which leads to the increase in USRGNP and EUSBT. Also apparent is when the US refused to accept any new orders, these denied orders show up as a drastic increase in RUOR (the ROW unfilled orders held by the ROW). However, because the US accounts for over 40% of all FMS (Ref 19) this sudden increase of force requests

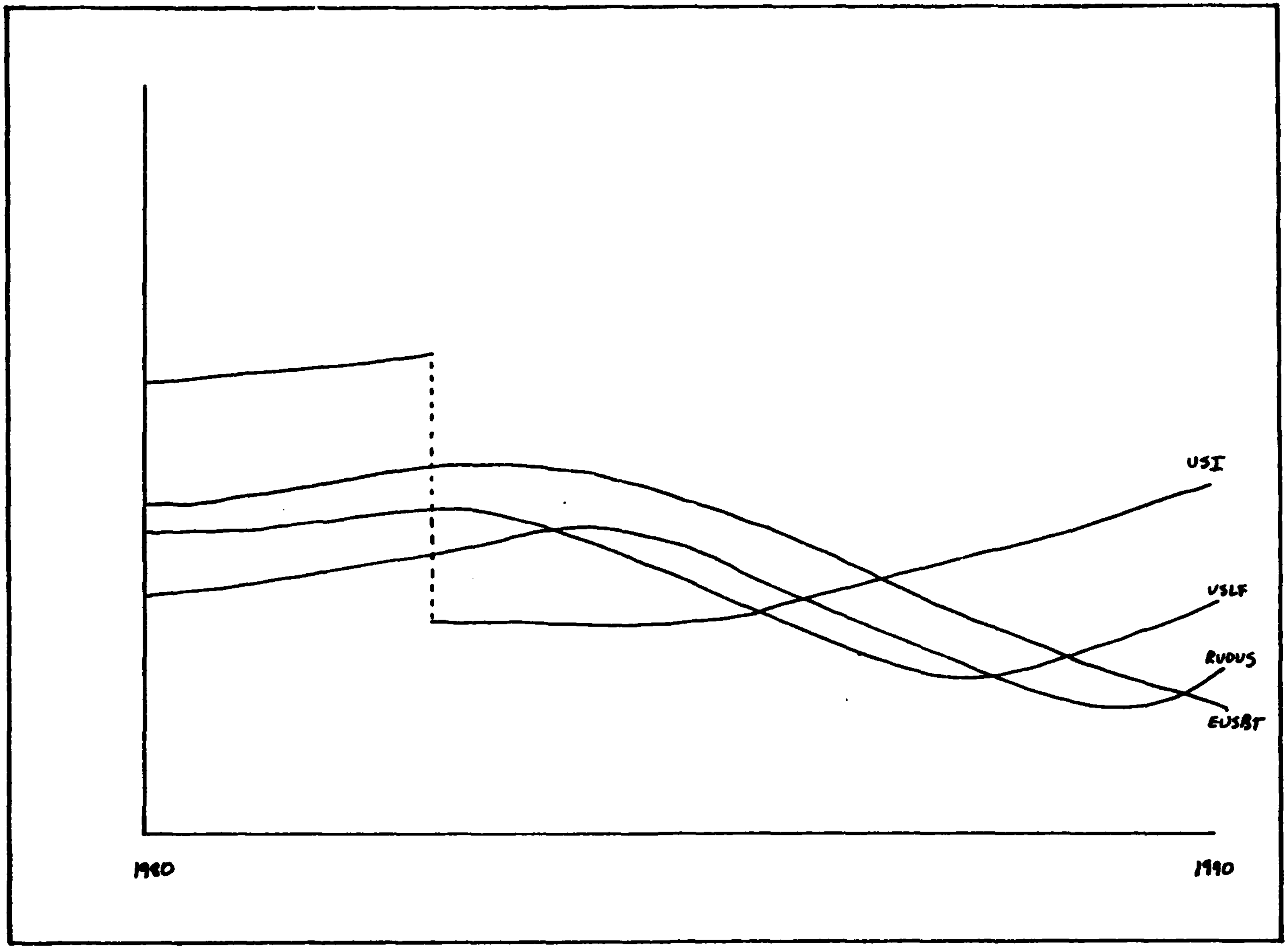


Figure 62. Plots For Experiment 1

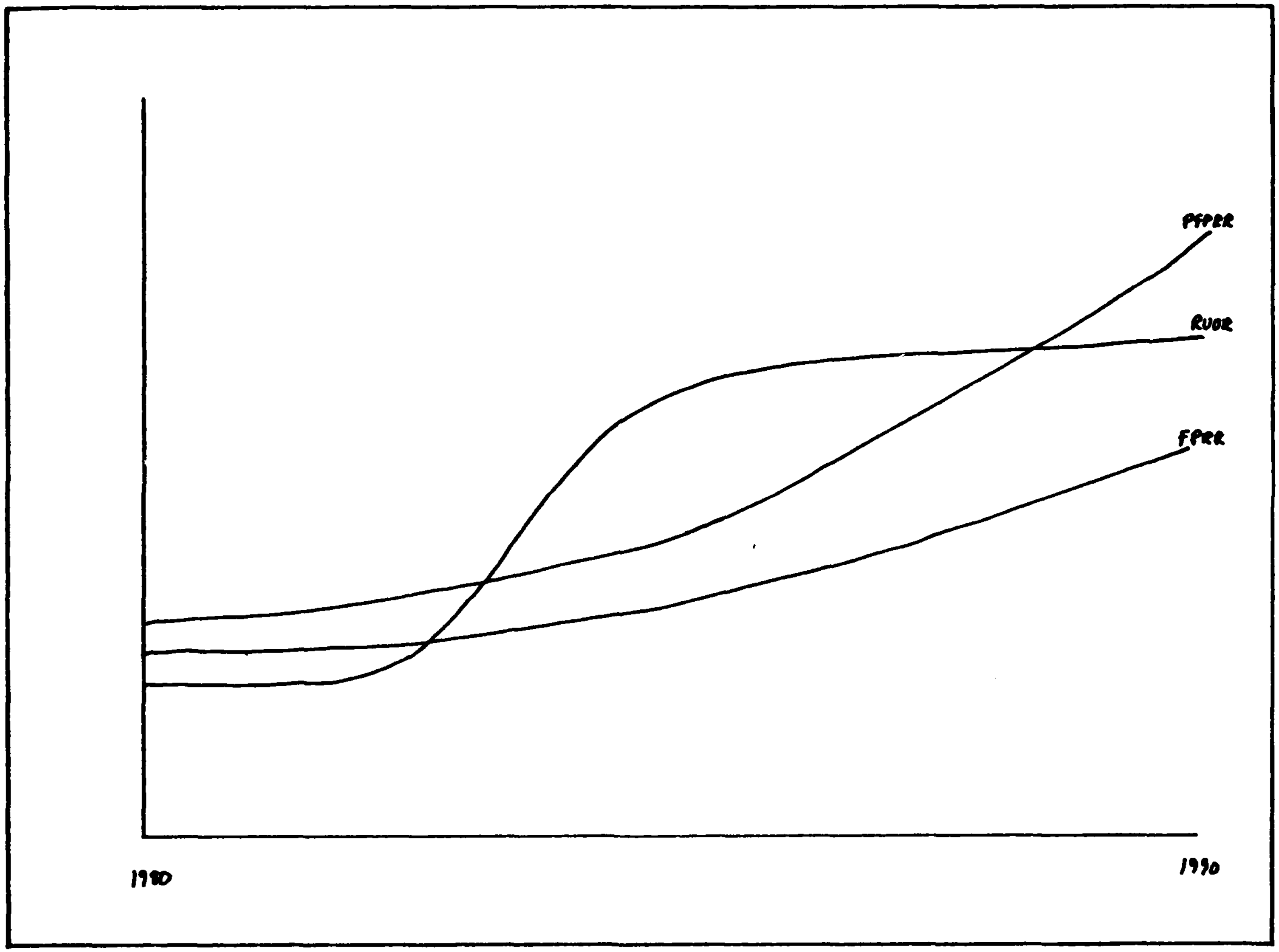


Figure 62. Plots For Experiment 1

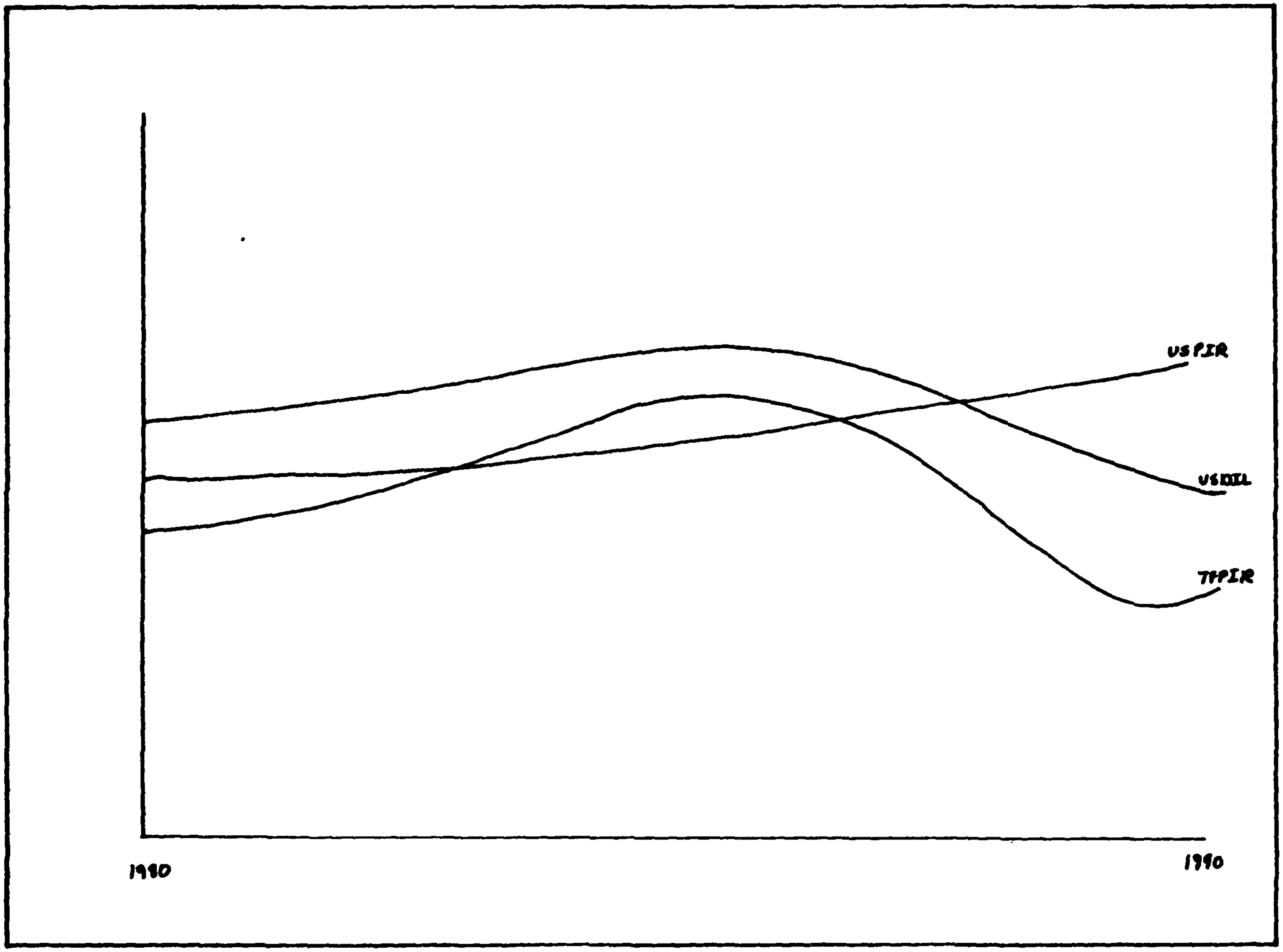


Figure 62. Plots For Experiment 1

on the ROW market cannot be handled by the ROW production industries. The level of ROW production tends to level out, increasing slowly as more capital is produced to increase production.

The overall behavior of the system behaved as expected, however, there are specific issues present in the real world that could not be modeled into the system. One of which is that in 1977 when President Carter placed a ceiling on the exportation of arms, the countries that were refused arms found other supplies. Today under the Reagan Administration with its open arms policy many of these countries which were denied arms in the past refuse or resist purchasing arms from the US (Ref 11). If indeed past buyers were to remain with their new found suppliers and not again purchase arms from the US, the recovery of USRGNP, USLF, and EUSBT would not be as rapid as shown. The recovery period would depend upon the severity of the ROW boycott and the ceiling placed on the US arms transfer system.

The concluding experiment done with the model was to attempt to show the effects foreign military sales have on world (regional) stability. This was a very difficult experiment because the word stability is very difficult to quantify into something that can be measured. Another problem is that even the world historians, economists, and politicians can't decide on the effects arms sales have on

world stability. If the intelligent men of the world cannot determine the effects of FMS on world stability it will be impossible to build a model that could. The purpose of this experiment, therefore, is to show that the model does indeed reflect reality in that as hostile neighboring countries increase their arms purchases, the neighboring countries do also.

By defining the hostile regions of the world and the relationships between the countries of the region, a hostility index was established, RHOST (the ROW hostility to the ROW). Therefore, if arms transfers do have a unstable effect on the world, arms purchases by one country should result in a reciprical purchase by its hostile neighbors. As an example, Israel and Egypt were selected and the results of the computer run are shown in Figure 63. From these figures it is obvious that as Israel arms purchases increased there was a similar increase in Egypts arms purchases. This increase by the Egyptians is slightly delayed which implies that the increase in Egypts arms purchases is a direct result of the Israeli force inventory and the perceived threat. This increase in arms purchases due to perceived threat is what this researcher has defined as "regional unstability." Therefore, based on RHOST, the model does support the premise that in hostile regions, arms purchases will result in a similar purchase by a neighboring country.

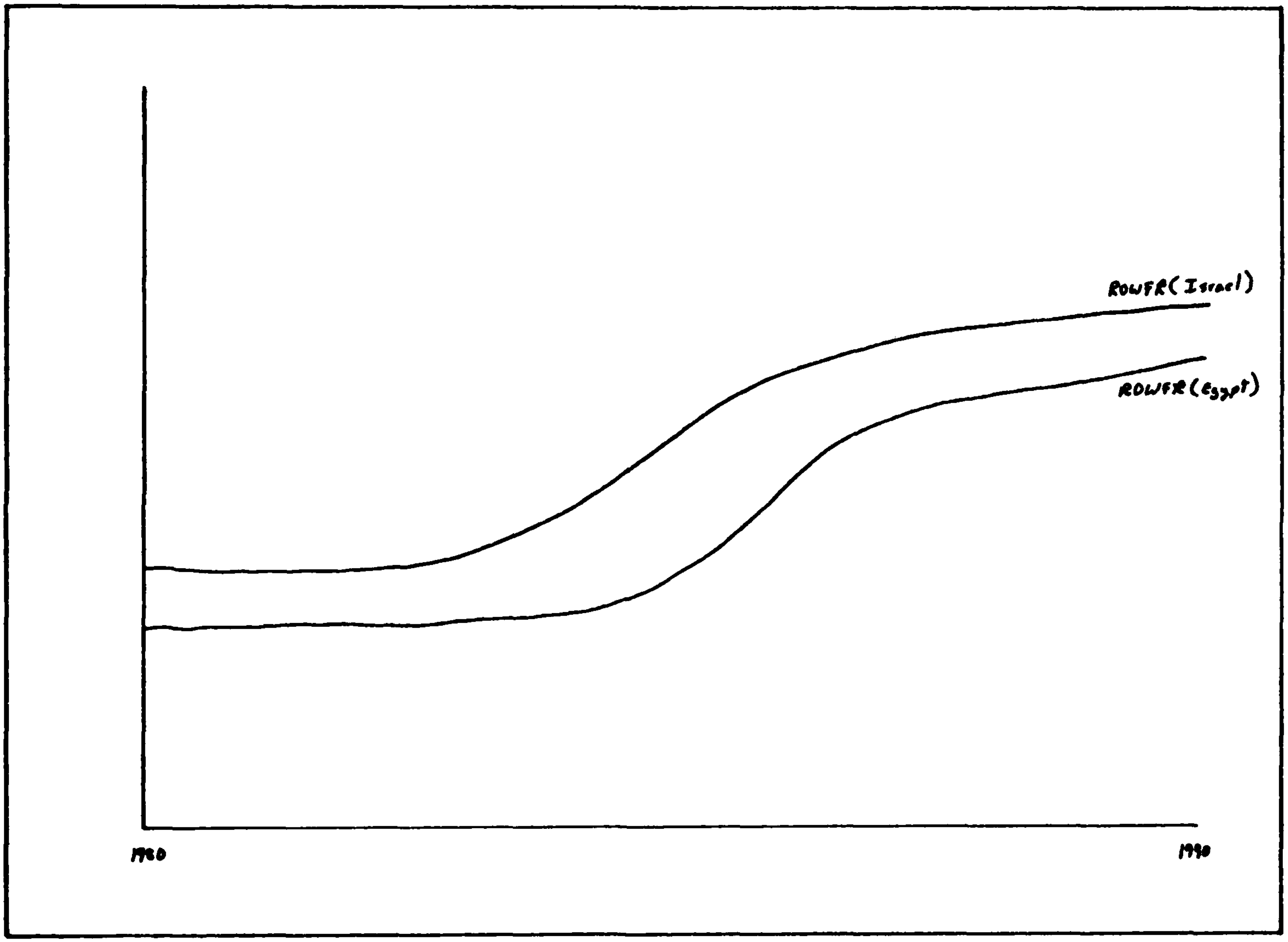


Figure 63. Plots For Experiment 2

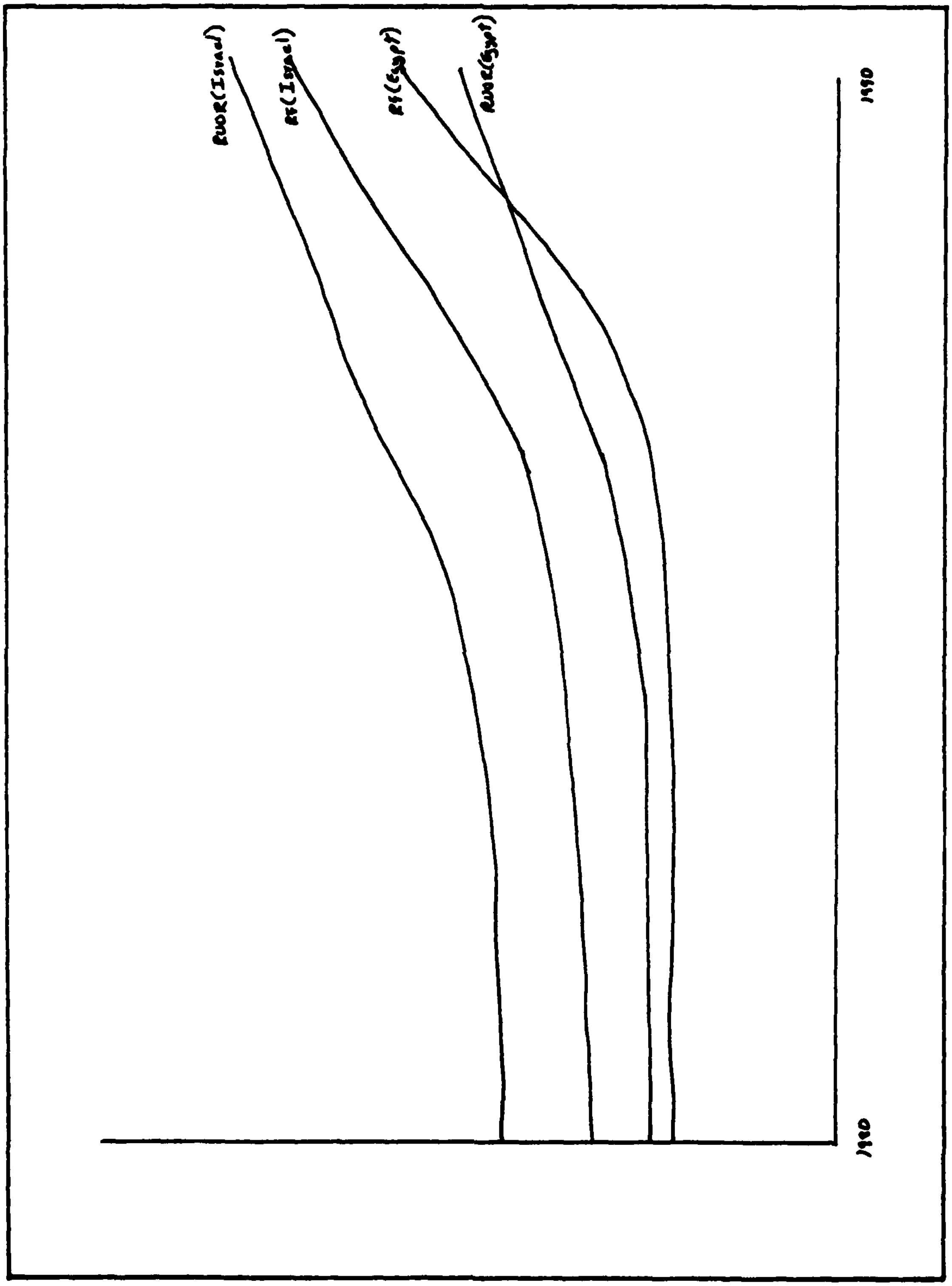


Figure 63. Plots For Experiment 2

Summary

The above report of the final experiment concludes this research effort. Chapter I provided a question for research. The following chapters detailed the search for a solution. Hence, it is now appropriate to relate the findings and conclusions drawn from this research effort.

VII. Summary, Conclusions, and Recommendations

Summary

The opening arguments of Chapter I presented background information on the US Arms Transfer Process. The problem at hand was then defined which leads to the formal statement of the problem. Following the problem statement was the justification of the research effort. The research objectives were then developed. Based on these objectives, a research methodology was selected and presented in Chapter II.

Chapter II provided the framework upon which this research effort was based. The appropriateness of using the System Dynamics Methodology was then presented which was followed by a discussion of the steps involved in developing a model using a system dynamics approach. With the discussion of the processes involved in developing a model, a review of the objectives is necessary to ensure that the intended tasks were accomplished.

The first two research objectives were: (1) to identify the structure of the arms transfer process, and (2) to identify the cause and effect feedback relationships which result from information changes within the arms transfer system. These first two objectives were addressed in Chapter III.

Chapter III presented the structure of the arms transfer process which was identified by using causal-loop diagrams. This causal structure provided a macro view of the arms transfer process. Based on this developed structure, the third research objective was addressed.

The third research objective was to construct a mathematical model which encompasses the identified factors, relationships, information flows, and decision policies. This objective was the force behind the discussion in Chapter IV. In this chapter, the development of the flows of money, material, orders, and information were used to build the decision structure of the model. To aid in this development, system flow diagrams were used to represent the accumulations, flows, and policy decisions. Based on these flow diagrams the mathematical model was developed. The insight gained in Chapter IV was necessary for the continuation of this research effort. This new understanding is one of the most important aspects of a modeling effort.

Research objective 4, and 5 were addressed in Chapter V. These objectives include: (1) Verification of the functional model on a sectors by sector bases and (2) to validate the model by showing that it behaves like the real world system.

Plots used in the validation process are provided in Chapter V. The data used in this modeling effort was

obtained from Air Force Logistics Command and the Defense Institute for Security Assistance Management. However, because of the sensitive nature of many arms transactions, the necessary data for the model was not available. Based on the relationships developed in Chapter IV, the soundness of the system structure was shown in the system output. After determining that indeed the model behaved as it should research objective six was addressed.

Research objective six, was to use the computer model as a vehicle to evaluate the effects policy changes, relating to foreign military sales, have on the US economy, and world stability. Two experiments were conducted with the end goal being increased understanding. These results were included to the text of Chpater VI.

As stated throughout this research effort the major benefit that results from this modeling effort appears to take the form of increased understanding. This understanding seems to be the key to unlocking the problem and determining a solution.

The research question stated in Chapter I presented the question as to the feasability of developing a model that could capture the nature of arms transfer process. Based on the results obtained, it appears that the true nature of the arms transfer process can be modeled.

Conclusions

The complexity of the US arms transfer process is evident in the scope of the system involved in the modeling effort. However, in spite of its complexity, the true behavior of the system can be modeled which provides a vehicle for increased understanding and continued policy analysis.

The model showed that in areas where the neighboring countries were not considered friendly, the purchase of arms by one country resulted in a similar purchase of arms by neighboring nations. The instability (tension) of a particular area was then determined based on the level of arms purchases in the region.

It is a major finding of this research effort that the US Arms Transfer Process can be incorporated into a dynamic model.

Recommendations

There are two recommendations for further research which have developed over the course of this research effort. The first recommendation is to continue the development of the model to include all the countries of the world so that the effects of new high technology weapons and the expense of acquiring and maintaining them can be studied in relation to the economic and military systems of third world developing nations. The second recommendation is to continue the model development so that it can be used as a tool to evaluate policy and decision alternatives. However, these recommendations are dependent upon two very critical factors: (1) the obtainment of the necessary data to do the research and (2) finding a computer system which has a large enough core capacity for the expanded model.

BIBLIOGRAPHY

References Cited

1. "Administration Sets Arms Transfer Guides," Aviation Week and Space Technology: 21 June 1, 1981.

2. "Arming the World," TIME: 21 October 1981.

3. Carter, Jimmy, President of the United States, Statement on Conventional Arms Transfer Policy, Washington, D.C., 19 May 1977.

4. Chipman, Douglas C. and John T. Cunningham, A Dynamic Policy Model of the United States Arms Trasnfer Process.

5. Crabe, William M. JR., and others. Security Assistance: Foreign Military Sales. Washington: Industrial College of the Armed Force, National Defense University, 1976.

6. The Encyclopedia Americana International Edition, Vol 17, New York: Americana Corporation, 1968.

7. Forrester, Jay W., Industrial Dynamics. Cambridge, Massachusetts: The MIT Press, 1961.

8. ________________, Principles of Systems. Cambridge, Massachusetts: The MIT Press, 1968.

9. Goodman, Michael R., Study Notes in Systems Dynamics. Cambridge, Massachusetts: The MIT Press, 1974.

10. Naylor, Thomas H. and J.M. Finger. "Verification of Computer Simulation Models," Management Science, 14(2): October, 1967.

11. Pierre, Andrew, J., The Global Politics of Arms Sales. Princeton, New Jersey: Princeton University Press, 1982.

12. Pugh, Alexander L., DYNAMO User's Manual. Cambridge, Massachusetts: The MIT Press, 1976.

13. Pugh, Alexander L. and George P. Richardson, Introduction to Systems Dynamics Modeling with DYNAMO. Cambridge, Massachusetts: The MIT Press, 1981.

14. Ra'anan, Vri, and Robert L. Pfaltzgraff. Arms Transfers to the World. Boulder Colorado: Westview Press, 1978.

15. Randers, Jorden. Elements of the System Dynamics Method. Cambridge, Massachusetts: The MIT Press, 1980.

16. Reigl, Peter, "ASPF Changes Made to Assist Military Sales," Defense Industry Bulletin, 1: 2-5 (May 1965).

17. Schoderbek, Charles G., Schoderbek, Peter P. and Kefalas, Asterios G. Management Systems: Conceptual Considerations. Dallas, Texas: Business Publications, Inc., 1975.

18. Shannon, Robert G. System Simulation. Englewood Cliffs NJ: Prentice Hall, Inc., 1975.

19. U.S. Congress. Congressional Budget Office. The Effects of Foreign Military Sales on the US Economy, Staff Working Paper. Washington: Government Printing Office, 23 July 1976.

20. US Department of Commerce, "Current Business Statistics," Survey on Current Business, Vol 58, No. 12 (December 1978).

APPENDICES

APPENDIX A

ARMS TRANSFER MODEL EQUATIONS

```
*
*
*          ******************************
*          **                          **
*          **    ARMS TRANSFER MODEL   **
*          **                          **
*          ******************************
*
*
*
C NCNTRY=18
C NCI=19
*
*   NCNTRY - NUMBER OF COUNTRIES IN MODEL EXCLUDING THE U.S.
*   NCI - NUMBER OF COUNTRIES IN MODEL INCLUDING THE U.S.
*
*
*          NEIGHBOR ARRAYS
*
T NEIGH(*,1)=2/1/1/8/3/3/5/3/5/19/12/11/12/1/
X 5/12/12/18/10
T NEIGH(*,2)=3/14/5/18/1/5/18/4/8/18/18/13/16/15/
X 14/13/13/18/18
T NEIGH(*,3)=5/17/6/18/6/18/18/9/18/18/18/16/17/16/
X 18/14/14/18/18
T NEIGH(*,4)=14/18/8/18/7/18/18/18/18/18/18/17/18/17/
X 18/17/16/18/18
*
*   NEIGH - TABLE REPRESENTING EACH COUNTRIES NEIGHBORS
*
*
FOR II=1,NCI
FOR I1=1,NCNTRY
FOR I2=1,3
FOR I3=1,4
FOR I4=2,NCNTRY
*
*   II - COUNTRY ARRAY INDEX INCLUDING U.S.
*   I1 - COUNTRY ARRAY INDEX
*   I2 - FORCE ARRAY INDEX
*   I3 - NEIGHBOR ARRAY INDEX
*   I4 -
*
*
FNCTN AMAX(2,0,1)
FNCTN AMAXX(3,0,1)
FNCTN AMAXXX(3,0,1)
FNCTN FIND1(6,0,11)
FNCTN FIND2(5,0,11)
FNCTN FIND3(6,0,111)
```

```
*
*   FNCTN - EXTERNAL FUNCTIONS USED IN THE MODEL
*
*
N TIME=1982
*
*   TIME - CURRENT TIME OF THE MODEL
*
*
```

```
*
* *******************************************************
* *    SECTOR  I  - U.S. FORCE REQUESTS                 *
* *******************************************************
*
*
*
*
R USFRRT.KL(1)=MAX(MAXNUC.K-USF.K(1)-USUO.K(1),0)
R USFRRT.KL(2)=MAX(MAXLTF.K-MAX(USF.K(1)-MAXNUC.K,0)-
X SUMV(USF.K,2,3)-SUMV(USUO.K,2,3),0)
R USFRRT.KL(3)=0
*
*  USFRRT - U.S. FORCE REQUESTS RATE
*  MAXNUC - MAXIMUM COUNTRY TACTICAL NUCLEAR THREAT TO U.S.
*  USUO - U.S. UNFILLED ORDERS
*  MAXLTF - MAXIMUM SINGLE COUNTRY THREAT TO U.S.
*  USF - U.S. FORCE INVENTORY
*
*
L USFR.K(I2)=USFR.J(I2)+DT*(USFRRT.JK(I2)-USFRPR.JK(I2))
N USFR(I2)=USFRI(I2)
T USFRI=300/100/500
*
R USFRPR.KL(I2)=DELAY3(USFRRT.JK(I2),USFRPD)
C USFRPD=.75
*
*  USFR - U.S. FORCE REQUESTS
*  USFRRT - U.S. FORCE REQUESTS RATE
*  USFRPR - U.S. FORCE REQUESTS PROCESSING RATE
*  USFRI - U.S. FORCE REQUESTS (INITIAL VALUES)
*  USFRPD - U.S. FORCE REQUESTS PROCESSING DELAY
*
*
L USFRP.K(I2)=USFRP.J(I2)+DT*(USFRPR.JK(I2)-
X USFRAR.JK(I2)-USFRDR.JK(I2))
N USFRP(I2)=USFRPI(I2)
T USFRPI=200/60/300
*
R USFRAR.KL(I2)=USPCFA.K*USFRP.K(I2)
*
R USFRDR.KL(I2)=(1-USPCFA.K)*USFRP.K(I2)
*
*  USFRP - U.S. FORCE REQUESTS PROCESSED
*  USFRPR - U.S. FORCE REQUESTS PROCESSING RATE
*  USFRAR - U.S. FORCE REQUESTS APPROVAL RATE
*  USFRDR - U.S. FORCE REQUESTS DENIAL RATE
*  USFRPI - U.S. FORCE REQUESTS PROCESSED (INITIAL VALUES)
*  USPCFA - U.S. PRESSURE ON CONGRESS FOR FORCE APPROPIATIONS
*
```

```
*
L USUO.K(I2)=USUO.J(I2)+DT*(USFRAR.JK(I2)-FDRTUS.JK(I2))
N USUO(I2)=USUOI(I2)
T USUOI=100/60/100
*
A NUCT.K(I1)=RF.K(I1,1)*USHOST(I1)
A MAXNUC.K=AMAX(NUCT.K,NCNTRY)
A ROWLTF.K(I1)=SUMV(RF.K(I1,*),2,3)
A MAXLTF.K(I1)=AMAX(ROWLTF.K,NCNTRY)
*
*  USUO - U.S. UNFILLED ORDERS
*  USUOI - U.S. UNFILLED ORDERS (INITIAL VALUES)
*  USFRAR - U.S. FORCE REQUESTS APPROVAL RATE
*  FDRTUS - FORCE DEPLOYMENT RATE BY U.S.
*  NUCT - SINGLE COUNTRY TACTICAL NUCLEAR THREAT TO U.S.
*  RF - REST OF WORLD FORCE INVENTORY
*  USHOST - PRECEIVED U.S. HOSTILITY TO REST OF WORLD
*  MAXNUC - MAXIMUM COUNTRY TACTICAL NUCLEAR THREAT TO U.S.
*  ROWLTF - REST OF WORLD SINGLE COUNTRY CONVENTIONAL THREAT
*  MAXLTF - MAXIMUM SINGLE COUNTRY CONVENTIONAL THREAT TO U.S
*
*
*
```

```
*
* ******************************************************
* *   SECTOR II  - U.S. PRESSURE ON CONGRESS FOR FORCE     *
* *                 APPROPRIATIONS                         *
* ******************************************************
*
*
*
*
A USPCFA.K=(W2*SUM(CFT.K)/RI.K+W3*ILP.K+W4*USPSFA.K+
X W5*(SUM(CT.K)-SUM(USF.K)-SUM(USUO.K))/SUM(USFR.K))/
X SUM(CFT.K)/RI.K
*
*  USPCFA - U.S. PRESSURE ON CONGRESS FOR FORCE APPROPRIATION
*  CFT - TOTAL COUNTRY FORCE REQUESTS
*  RI - REGIONAL INSTABILITY
*  ILP - INDUSTRY LOBBY PRESSURE
*  USPSFA - U.S. POPULAR SUPPORT FOR FORCE APPROPRIATIONS
*  CT - SINGLE COUNTRY THREAT TO U.S.
*  USF - U.S. FORCE INVENTORY
*  USUO - U.S. UNFILLED ORDERS
*  USFR - U.S. FORCE REQUESTS
*  CRF -
*
*
C W1=1
C W2=.2
C W3=.6
C W4=1.2
C W5=2
*
*  W1 - INDUSTRIAL LOBBY INTERNAL WEIGHING FACTOR
*  W2 TO W5 - U.S. PRESSURE ON CONGRESS WEIGHTING FACTORS
*
*
A CFT.K(I1)=ROWFR.K(I1)*ROWIUS(I1)+.01
*
A CRF.K(I1)=SUMV(RF.K(I1,*),1,3)*USHOST(I1)
*
A ILP.K=0.4
*
*  CFT - TOTAL COUNTRY FORCE REQUESTS
*  ROWFR - REST OF WORLD FORCE REQUESTS
*  ROWIUS - REST OF WORLD IMPORTANCE TO U.S.
*  RF - REST OF WORLD FORCE INVENTORY
*  USHOST - PRECEIVED U.S. HOSTILITY TO REST OF WORLD
*  ILP - INDUSTRY LOBBY PRESSURE
*  RUOUS - REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORL
*  USUO - U.S. UNFILLED ORDERS
*  USCAP - U.S. CAPITAL INVENTORY
```

```
*  FPC - U.S. FORCE PRODUCTION CAPACITY
*
*
A USPSFA.K=0.7
*
A CT.K(I1)=SUMV(RF.K(I1,*),1,3)*USHOST(I1)
*
A FPC.K(I2)=SUMV(FIPUS.K(*,I2),1,NCI)*FPDUS(I2)
*
A RI.K=SUM(ROWFR.K)+.01
*
C DEP=.95
C DACGR=.03
C GNPSC=3
C USFSC=2
C DFGR=3
*
*  USPSFA - U.S. POPULAR SUPPORT FOR FORCE APPROPRIATIONS
*  DEP - U.S. DESIRED EMPLOYMENT PERCENTAGE
*  USLF - U.S. LABOR FORCE
*  DAGR - U.S. DESIRED ANNUAL GNP GROWTH RATE
*  USRGNP - U.S. REAL GROSS NATIONAL PRODUCT
*  GNPSC - U.S. GNP SMOOTHING CONSTANT
*  CFT - TOTAL COUNTRY FORCE REQUESTS
*  USFR - U.S. FORCE REQUESTS
*  DFGR - U.S. DESIRED FORCE GROWTH RATE
*  USTF - U.S. TOTAL FORCE
*  USFSC - U.S. FORCE SMOOTHING CONSTANT
*  CT - SINGLE COUNTRY THREAT TO U.S.
*  RF - REST OF WORLD FORCE INVENTORY
*  USHOST - PRECEIVED U.S. HOSTILITY TO REST OF WORLD
*  FPC - U.S. FORCE PRODUCTION CAPACITY
*  FIPUS - FORCES IN PRODUCTION BY U.S.
*  FPDUS - FORCE PRODUCTION DELAY IN U.S.
*  RI - REGIONAL INSTABILITY
*  ROWFR - REST OF WORLD FORCE REQUESTS
*
*
*
```

```
*
* ***********************************************************
* *   SECTOR III - U.S. PRODUCTION CYCLE                      *
* ***********************************************************
*
*
*
R PFPRUS.KL(I1,I2)=RUOUS.K(I1,I2)*MAX(0,USCAP.K(I2)-
X USUO.K(I2))/SUMV(RUOUS.K(*,I2),1,NCNTRY)
*
R PFPRUS.KL(NCI,I2)=MIN(USCAP.K(I2),USUO.K(I2))
*
*   PFPRUS - PLANNED FORCE PRODUCTION RATE BY U.S.
*   RUOUS - REST OF WORLD UNFILLED ORDERS HELD BY U.S.
*   USCAP - U.S. CAPITAL INVENTORY
*   USUO - U.S. UNFILLED ORDERS
*
*
L FIPUS.K(II,I2)=FIPUS.J(II,I2)+DT*(PFPRUS.JK(II,I2)-
X FPRTUS.JK(II,I2))
N FIPUS(II,I2)=FIPUSI(II,I2)
*
T FIPUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/100
T FIPUSI(*,2)=0/80/10/0/0/10/10/0/0/0/0/10/20/0/0/10/0/0/80
T FIPUSI(*,3)=0/100/20/0/0/20/20/0/0/0/0/20/40/0/0/20/0/0/180
*
*   FIPUS - FORCES IN PRODUCTION BY U.S.
*   FIPUSI - FORCES IN PRODUCTION BY U.S. ( INITIAL VALUES )
*   PFPRUS - PLANNED FORCE PRODUCTION RATE BY U.S.
*   FPRTUS - FORCE PRODUCTION RATE BY U.S.
*
R FPRTUS.KL(II,I2)=DELAY3(PFPRUS.JK(II,I2),FPDUS(I2))
T FPDUS=3/3/3
*
L CFPUS.K(I1,I2)=CFPUS.J(I1,I2)+DT*(FPRTUS.JK(I1,I2)-
X FDRR.JK(I1,I2))
*
L CFPUS.K(NCI,I2)=CFPUS.J(NCI,I2)+DT*(FPRTUS.JK(NCI,I2)-
X FDRTUS.JK(I2))
N CFPUS(II,I2)=CFPUSI(II,I2)
*
T CFPUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T CFPUSI(*,2)=0/10/3/0/0/3/3/0/0/0/0/3/7/0/0/3/0/0/100
T CFPUSI(*,3)=0/25/5/0/0/5/5/0/0/0/0/5/8/0/0/5/0/0/100
*
*   FPRTUS - FORCE PRODUCTION RATE BY U.S.
*   PFPRUS - PLANNED FORCE PRODUCTION RATE BY U.S.
*   FPDUS - FORCE PRODUCTION DELAY IN U.S.
*   CFPUS - COMPLETED FORCE PRODUCTION BY U.S.
*   CFPUSI - COMPLETED FORCE PRODUCTION BY U.S. ( INITIAL VALU
```

```
*   FDRR - FORCE DEPLOYMENT RATE BY REST OF WORLD (U.S. PRODUC
*   FDRTUS - FORCE DEPLOYMENT RATE BY U.S.
*
*
R FDRTUS.KL(I2)=CFPUS.K(NCI,I2)
*
R FDRR.KL(I1,I2)=CFPUS(I1,I2)
*
*   FDRTUS - FORCE DEPLOYMENT RATE BY U.S.
*   FDRR - FORCE DEPLOYMENT RATE BY REST OF WORLD (U.S. PRODUC
*
*
*
```

```
*
* ************************************************************
* *   SECTOR IV - DEPLOYMENT OF U.S. FORCES OVERSEAS        *
* ************************************************************
*
*
*
*
*
L USFC.K(I2)=USFC.J(I2)+DT*(FDRTUS.JK(I2)-SUMV(USFODR.JK
X (*,I2),1,NCNTRY)-USCFRR.JK(I2))
N USFC(I2)=USFCI(I2)
T USFCI=0/401/1307
*
*   USFC - U.S. FORCES IN CONUS
*   USFCI - U.S. FORCES IN CONUS (INITIAL VALUES)
*   FDRTUS - FORCE DEPLOYMENT RATE BY U.S.
*   USFODR - U.S. FORCES OVERSEAS DEPLOYMENT RATE
*   USCFRR - U.S. CONUS FORCES RETIREMENT RATE
*
*
R USFODR.KL(I1,1)=MIN((MAX(0,(AMAXXX(NFN.K,NCNTRY,I1)-
X RF.K(I1,1)-USFO.K(I1,1)))*MIN(USIROW(I1),ROWIUS(I1))),
X ((USF.K(1)*OSFRAC(1))-SUMV(USFO.K(*,1),1,NCNTRY)))
*
R USFODR.KL(I1,2)=MIN(((MAX(0,ROWFR.K(I1)-SUMV(RF.K(I1,*),1,3)
X -SUMV(USFO.K(I1,*),1,3)-USFODS.K(I1,1)))*MIN(USIROW(I1),
X ROWIUS(I1))),MAX(0,(SUM(USFTO)-SUM(USFO))))
*
R USFODR.KL(I1,3)=0
*
*   USFODR - U.S. FORCES OVERSEAS DEPLOYMENT RATE
*   NFN - NEIGHBORS THREAT TO REST OF WORLD
*   RF - REST OF WORLD FORCE INVENTORY
*   USFO - U.S. FORCES OVERSEAS
*   USIROW - U.S. IMPORTANCE TO REST OF WORLD
*   ROWIUS - REST OF WORLD IMPORTANCE TO U.S.
*   USF - U.S. FORCE INVENTORY
*   OSFRAC - OVERSEAS DEPLOYMENT FRACTION
*   ROWFR - REST OF WORLD FORCE REQUESTS
*   USFODS - U.S. FORCES OVERSEAS DEPLOYMENT RATE (INTERIM VAL
*   USFTO - MAXIMUN U.S. FORCES DEPLOYABLE OVERSEAS
*
L USFO.K(I1,I2)=USFO.J(I1,I2)+DT*(USFODR.JK(I1,I2)-
X USOFRR.JK(I1,I2))
N USFO(I1,I2)=USFOI(I1,I2)
T USFOI(*,1)=0/7350/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T USFOI(*,2)=0/265/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T USFOI(*,3)=0/615/72/0/0/144/0/96/0/0/0/0/0/0/0/0/0/0
*
```

```
*  USFO - U.S. FORCES OVERSEAS
*  USFOI - U.S. FORCES OVERSEAS (INITIAL VALUES)
*  USFODR - U.S. FORCES OVERSEAS DEPLOYMENT RATE
*  USOFRR - U.S. OVERSEAS FORCES RETIREMENT RATE
*
*
R USOFRR.KL(I1,I2)=DELAY3(USFODR.JK(I1,I2),USFL(I2))
R USCFRR.KL(I2)=DELAY3(FDRTUS.JK(I2),USFL(I2))
T USFL=5/15/10
*
A NFN.K(I1,I2,I3)=NF.K(I1,I2,I3)*RHOST(I1,I3)
A NF.K(I1,I2,I3)=FIND1(RF.K,NEIGH,I1,I2,I3,NCI)
*
*  USOFRR - U.S. OVERSEAS FORCES RETIREMENT RATE
*  USFODR - U.S. FORCES OVERSEAS DEPLOYMENT RATE
*  USCFRR - U.S. CONUS FORCES RTIREMENT RATE
*  FDRTUS - FORCE DEPLOYMENT RATE BY U.S.
*  NFN - NEIGHBORS THREAT TO REST OF WORLD
*  NF - NEIGHBORING COUNTRY FORCE
*  RHOST - PRECEIVED REST OF WORLD HOSTILITY TO REST OF WORLD
*  RF - REST OF WORLD FORCE INVENTORY
*  NEIGH - TABLE OF EACH COUNTRIES NEIGHBORS
*
*
T RHOST(*,1)=1/1/.5/0/0/0/1/0/1/.7/.8/1/.7/.3/.5/.4/1/0/.7
T RHOST(*,2)=.5/.1/0/0/1/1/0/0/1/0/0/.7/.4/1/1/.4/1/0/0
T RHOST(*,3)=.1/.1/0/0/.6/0/0/1/0/0/0/.4/1/1/0/1/1/0/0
T RHOST(*,4)=0/0/0/0/1/0/0/0/0/0/0/1/0/1/0/1/1/0/0
*
T USIROW=0/1/1/1/.2/1/.8/.3/0/0/0/.3/.6/0/0/.5/0/0
*
T ROWIUS=0/1/1/1/0/.4/.3/.3/0/0/0/.4/.5/.2/.3/.6/.2/0
*
T OSFRAC=1/.33/.33
*
*  RHOST - PRECEIVED REST OF WORLD HOSTILITY TO REST OF WORLD
*  USIROW - U.S. IMPORTANCE TO REST OF WORLD
*  ROWIUS - REST OF WORLD IMPORTANCE TO U.S.
*  OSFRAC - OVERSEAS DEPLOYMENT FRACTION
*  USFC - U.S. FORCES IN CONUS
*  USFO - U.S. FORCES OVERSEAS
*
*
A USF.K(I2)=USFC.K(I2)+SUMV(USFO.K(*,I2),1,NCNTRY)
*
A USFODS.K(I1,1)=MIN((MAX(0,(AMAXXX(NFN.K,NCNTRY,I1)-
X RF.K(I1,1)-USFO.K(I1,1)))*MIN(USIROW(I1),ROWIUS(I1))),
X ((USF.K(1)*OSFRAC(1))-SUMV(USFO.K(*,1),1,NCNTRY)))
*
A USFTO.K(I2)=USF.K(I2)*OSFRAC(I2)
```

```
*
*  USF - U.S. FORCE INVENTORY
*  USFC - U.S. FORCES IN CONUS
*  USFO - U.S. FORCES OVERSEAS
*  NFN - NEIGHBORS THREAT TO REST OF WORLD
*  RF - REST OF WORLD FORCE INVENTORY
*  USIROW - U.S. IMPORTANCE TO REST OF WORLD
*  ROWIUS - REST OF WORLD IMPORTANCE TO U.S.
*  OSFRAC - OVERSEAS DEPLOYMENT FRACTION
*  USFTO - MAXIMUN U.S. FORCES DEPLOYABLE OVERSEAS
*
*
*
```

```
*
* **********************************************************
* *   SECTOR V - U.S. PRODUCTION CAPACITY                  *
* **********************************************************
*
*
*
R USPCPR.KL(I2)=MIN(SMOOTH(CSF.K(I2),USCPH),USDIL.K/CP(I2)*
X MUSCIP*SMOOTH(CSF.K(I2),USCPH)/SMOOTH(TCSF.K,USCPH))
*
*   USPCPR - U.S. PLANNED CAPITAL PRODUCTION RATE
*   CSF - CAPITAL SHORTFALL
*   USCPH - U.S. CAPITAL PRODUCTION PLANNING HORIZON
*   USDIL - U.S. DEFENSE INDUSTRY LIQUIDITY
*   MUSCIP - MAXIMUN PROPORTION OF U.S. INDUSTRY LIQUIDITY AVA
*            FOR CAPITAL PRODUCTION
*   TCSF - TOTAL CAPITAL SHORTFALL
*   CP - CAPITAL PRICE
*
A UO.K(I2)=USUO.K(I2)+SUMV(RUOUS.K(*,I2),1,NCNTRY)
*
C USCPH=5
C MUSCIP=.075
*
A CSF.K(I2)=UO.K(I2)/FPDUS(I2)-USCAP.K(I2)
*
A TCSF.K(I2)=CSF.K(1)+CSF.K(2)+.01
*
*   UO - UNFILLED ORDERS
*   USUO - U.S. UNFILLED ORDERS
*   RUOUS - REST OF WORLD UNFILLED ORDERS HELD BY U.S.
*   USCPH - U.S. CAPITAL PRODUCTION PLANNING HORIZON
*   MUSCIP - MAXIMUN PROPORTION OF U.S. INDUSTRY LIQUIDITY AVA
*            FOR CAPITAL PRODUCTION
*   CSF - CAPITAL SHORTFALL
*   FPDUS - FORCE PRODUCTION DELAY IN U.S.
*   USCAP - U.S. CAPITAL INVENTORY
*
*
L USCIP.K(I2)=USCIP.J(I2)+DT*(USCPR.JK(I2)-USCRRT.JK(I2))
N USCIP(I2)=USCIPI(I2)
T USCIPI=100/200/300
*
R USCPR.KL(I2)=DELAY3(USPCPR.JK(I2),USCPD)
C USCPD=5
*
*   USCIP - U.S.CAPITAL IN PRODUCTION
*   USCPR - U.S. CAPITAL PRODUCTION RATE
*   USCRRT - U.S. CAPITAL RETIREMENT RATE
*   USCIPI - U.S. CAPITAL IN PRODUCTION (INITIAL VALUES)
```

```
*   USPCPR - U.S. PLANNED CAPITAL PRODUCTION RATE
*   USCPD - U.S. CAPITAL PRODUCTION DELAY
*
*
L USCAP.K(I2)=USCAP.J(I2)+DT*(USCPR.JK(I2)-USCRRT.JK(I2))
N USCAP(I2)=USCAPI(I2)
T USCAPI=200/300/350
*
R USCRRT.KL(I2)=DELAY3(USCPR.JK(I2),USCL(I2))
T USCL=25/30/20
*
T CP=.06/.048/.008
*
*   USCAP - U.S. CAPITAL INVENTORY
*   USCPR - U.S. CAPITAL PRODUCTION RATE
*   USCRRT - U.S. CAPITAL RETIREMENT RATE
*   USCAPI - U.S. CAPITAL INVENTORY (INITIAL VALUES)
*   USCL - U.S. CAPITAL LIFE
*   CP - CAPITAL PRICE
*
*
*
*
```

```
      :
* ***********************************************************
* *   SECTOR VI - ARMS PAYMENT TO PRODUCTIONSECTOR           *
* ***********************************************************
*
*
*
*
R PTFRT.KL(I1)=SUMV(PTFRTI.K(I1,*),1,3)
*
A PTFRTI.K(I1,I2)=FP(I2)*MIN(RUOUS.K(I1,I2)/FPDUS(I2)
X ,RUOUS.K(I1,I2)/SUMV(RUOUS.K(*,I2),1,NCNTRY)*
X MAX(USCAP.K(I2)-USUO.K(I2)/FPDUS(I2),0))
*
*   PTFRT - PAYMENT TO TRUST FUND RATE
*   PTFRTI - PAYMENT TO TRUST FUND RATE (INTERIM VALUE)
*   FP - FORCE PRICE
*   RUOUS - REST OF WORLD UNFILLED ORDERS HELD BY U.S.
*   FPDUS - FORCE PRODUCTION DELAY IN U.S.
*   USCAP - U.S. CAPITAL INVENTORY
*   USUO - U.S. UNFILLED ORDERS
*
*
L TF.K(I1)=TF.J(I1)+DT*(PTFRT.JK(I1)-TFPIR.JK(I1))
N TF(I1)=TFI(I1)
T TFI=0/20/10/5/0/0/5/0/0/0/0/10/0/0/0/0/0
*
R TFPIR.KL(I1)=SUMV(TFPIRI.K(I1,*),1,3)
A TFPIRI.K(I1,I2)=FP(I2)*CFPUS(I1,I2)
*
R USART.KL(I2)=USPCFA.K*USFRP.K(I2)*FP(I2)
*
*   TF - TRUST FUND
*   TFI - TRUST FUND (INITIAL VALUES)
*   PTFRT - PAYMENT TO TRUST FUND RATE
*   TFPIR - TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE
*   FP - FORCE PRICE
*   CFPUS - COMPLETED FORCE PRODUCTION BY U.S.
*   USART - U.S. APPROPRIATIONS RATE
*   USPCFA - U.S. PRESSURE ON CONGRESS FOR FORCE APPROPRIATION
*   USFRP - U.S. FORCE REQUESTS PROCESSED
*
*
L USFA.K(I2)=USFA.J(I2)+DT*(USART.JK(I2)-USPIR.JK(I2))
N USFA(I2)=USFAI(I2)
T USFAI=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
*
R USPIR.KL(I2)=SUM(USPIRI.K)
A USPIRI.K(I2)=FP(I2)*CFPUS.K(NCI,I2)
*
```

```
*   USFA - U.S. FORCE APROPRIATIONS
*   USFAI - U.S. FORCE APPROPRIATIONS (INITIAL VALUES)
*   USART - U.S. APPROPRIATIONS RATE
*   USPIR - U.S. PAYMENT TO DEFENSE INDUSTRY RATE
*   FP - FORCE PRICE
*   CFPUS - COMPLETED FORCE PRODUCTION BY U.S.
*
*
L USDIL.K=USDIL.J+DT*(SUM(TFPIR.JK)+USPIR.JK-USILDR.JK)
N USDIL=USDILI
C USDILI=0
*
R USILDR.KL=ILP.K*LP+SUM(FPR.K)+SUM(CPR.K)+DC*USDIL.K
*
C DC=.075
C LP=.01
T FC=.085/.068/.01
*
A FPR.K(I2)=(SUMV(FPRTUS.JK(*,I2),1,NCNTRY)+
X FPRTUS.JK(NCI,I2))*FC(I2)
*
A CPR.K(I2)=USCPR.JK(I2)*CP(I2)
*
*   USDIL - U.S. DEFENSE INDUSTRY LIQUIDITY
*   TFPIR - TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE
*   USPIR - U.S. PAYMENT TO DEFENSE INDUSTRY RATE
*   UDILDR - U.S. DEFENSE INDUSTRY LIQUIDITY DEPLETION RATE
*   ILP - INDUSTRY LOBBY PRESSURE
*   LP - LOBBY PRICE
*   FPR - FORCE PAYMENT RATE
*   CPR - CAPITAL PAYMENT RATE
*   DC - DISBURSEMENT CONSTANT
*   USDIL - U.S. DEFENSE INDUSTRY LIQUIDITY
*   FC - FORCE COST
*   FPRTUS - FORCE PRODUCTION RATE BY U.S.
*   USCPR - U.S. CAPITAL PRODUCTION RATE
*   CP - CAPITAL PRICE
*
*
*
```

```
*
* *********************************************************
* *   SECTOR VII - REST OF WORLD PRODUCTION CYCLE          *
* *********************************************************
*
*
*
*
R PFPRR.KL(I1,I2)=MIN(SUMV(ROWCAP(*,I2),1,NCNTRY)*
X RUOR.K(I1,I2)/SUMV(RUOR.K(*,I2),1,NCNTRY),RUOR.K(I1,I2))
*
L FIPR.K(I1,I2)=FIPR.J(I1,I2)+DT*(PFPRR.JK(I1,I2)-
X FPRR.JK(I1,I2))
N FIPR(I1,I2)=FIPRI(I1,I2)
T FIPRI(*,1)=90/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T FIPRI(*,2)=200/100/100/0/0/0/0/0/0/0/0/0/50/0/0/0/0/0
T FIPRI(*,3)=200/100/100/20/0/0/0/0/0/0/0/0/30/0/0/0/0/0
*
R FPRR.KL(I1,I2)=DELAY3(PFPRR.JK(I1,I2),FPDROW(I2))
T FPDROW=3/3/3
*
*   PFPRR - PLANNED FORCE PRODUCTION RATE BY REST OF WORLD
*   ROWCAP - REST OF WORLD CAPITAL INVENTORY
*   RUOR - REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD
*   FIPR - FORCES IN PRODUCTION BY REST OF WORLD
*   FPRR - FORCE PRODUCTION RATE BY REST OF WORLD
*   FIPRI - FORCES IN PROCUCTION BY REST OF WORLD (INITIAL VAL
*   FPDROW - FORCE PRODUCTION DELAY IN REST OF WORLD
*
*
L RF.K(I1,I2)=RF.J(I1,I2)+DT*(FDRR.JK(I1,I2)+
X FPRR.JK(I1,I2)-RFRR.JK(I1,I2))
L RF.K(NCI,I2)=USF.J(I2)
N RF(I1,I2)=RFI(I1,I2)
N RF(NCI,I2)=USFC(I2)+SUMV(USFO(*,I2),1,NCNTRY)
T RFI(*,1)=3500/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T RFI(*,2)=1532/288/9/22/0/0/0/0/0/0/12/21/25/56/0/20/142/0
T RFI(*,3)=1078/2070/248/48/20/198/209/13/30/0/65/135/250/
X 410/100/169/150/0
*
*   RF - REST OF WORLD FORCE INVENTORY
*   FDRR - FORCE DEPLOYMENT RATE BY REST OF WORLD (U.S. PRODUC
*   FPRR - FORCE PRODUCTION RATE BY REST OF WORLD
*   RFRR - REST OF WORLD FORCE RETIREMENT RATE
*   USF - U.S. FORCE INVENTORY
*   USFC - U.S. FORCES IN CONUS
*   USFO - U.S. FORCES OVERSEAS
*   RFI - REST OF WORLD FORCE INVENTORY (INITIAL VALUES)
*
*
```

```
R RFRR.KL(I1,I2)=DELAY3(FDRR.JK(I1,I2)+FPRR.JK(I1,I2),ROWFL(I2))
T ROWFL=5/15/10
*
T ROWCAP(*,1)=750/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T ROWCAP(*,2)=480/200/125/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T ROWCAP(*,3)=500/530/125/30/0/0/45/0/0/0/0/0/120/0/30/0/0/0
*
*   RFRR - REST OF WORLD FORCE RETIREMENT RATE
*   FDRR - FORCE DEPLOYMENT RATE BY REST OF WORLD (U.S. PRODUC
*   FPRR - FORCE PRODUCTION RATE BY REST OF WORLD
*   ROWFL - REST OF WORLD FORCE LIFE
*   ROWCAP - REST OF WORLD CAPITAL INVENTORY
*
*
*
```

```
*
* ***********************************************************
* *   SECTOR VIII - REST OF WORLD FORCE REQUESTS            *
* ***********************************************************
*
*
*
*
A ROWFR.K(I1)=AMAXX(RFRI.K,NCNTRY,I1)+USTF.K*
X USHOST(I1)-ROWTF.K(I1)-SUMV(RFRA.K(I1,*),1,3)-
X SUMV(RFOT.K(I1,*),1,3)-SUMV(RORUS.K(I1,*),1,3)-
X SUMV(ROPUS.K(I1,*),1,3)-SUMV(RUOUS.K(I1,*),1,3)-
X SUMV(RUOR.K(I1,*),1,3)-SUMV(USFO.K(I1,*),1,3)+
X AMAXX(RFRIR.K,NCNTRY,I1)
*
*  ROWFR - REST OF WORLD FORCE REQUESTS
*  RFRI - REST OF WORLD FORCE REQUESTS (INPUT)
*  USTF - U.S. TOTAL FORCE
*  USHOST - PRECEIVED U.S. HOSTILITY TO REST OF WORLD
*  ROWTF - REST OF WORLD TOTAL FORCE BY COUNTRY
*  RFRA - REST OF WORLD FORCE REQUESTS APPROVED
*  RFOT - REST OF WORLD FOREIGN ORDERS TOTAL
*  RORUS - REST OF WORLD ORDERS RECEIVED BY U.S.
*  ROPUS - REST OF WORLD ORDERS TO U.S. PROCESSED
*  RUOUS - REST OF WORLD UNFILLED ORDERS HELD BY U.S.
*  RUOR - REST OF WORLD UNFILLED ORERS HELD BY REST OF WORLD
*  USFO - U.S. FORCES OVERSEAS
*  RFRIR - REST OF WORLD OFFENSIVE FORCE REQUIRED (INPUT)
*
*
A RFRI.K(I1,I3)=FIND3(RHOST,NEIGH,ROWTF,I1,I3,NCI)
*
A RFRIR.K(I1,I3)=RHOST(I1,I3)*FIND2(ROWTF.K,NEIGH,I1,I3,NCI)
*
A USTF.K=SUM(USF.K)
*
A ROWTF.K(I1)=SUMV(RF.K(I1,*),1,3)
A ROWTF.K(NCI)=USTF.K
*
*  RFRI - REST OF WORLD FORCE REQUESTS (INPUT)
*  RHOST - PRECEIVED REST OF WORLD HOSTILITY TO REST OF WORLD
*  NEIGH - TABLE CONTAINING EACH COUNTRIES NEIGHBORS
*  ROWTF - REST OF WORLD TOTAL FORCE BY COUNTRY
*  RFPIR - REST OF WORLD OFFENSIVE FORCE REQUESTS (INPUT)
*  USTF - U.S. TOTAL FORCE
*  USF - U.S. FORCE INVENTORY
*  RF - REST OF WORLD FORCE INVENTORY
*
*
*
```

```
*
* ********************************************************
* *   SECTOR IX - REST OF WORLD FORCE REQUESTS            *
* ********************************************************
*
*
*
*
*
R RFRART.KL(1,1)=MAX(0,USF.K(1)*DNF6-RF.K(1,1)-RUOR.K(1,1))
R RFRART.KL(I[illegible],1)=0
R RFRART.KL(I1,2)=MIN(ROWFR.K(I1),MAX(0,(ROWFR.K(I1)*
X FP(3)-RAVAL.K(I1))/(FP(3)-FP(2))))
R RFRART.KL(I1,3)=MAX(0,MIN((RAVAL.K(I1)-FP(2)*ROWFR.K
X (I1))/(FP(3)-FP(2)),RAVAL.K(I1)/FP(3)))
*
*   RFRART - REST OF WORLD FORCE REQUESTS APPROVAL RATE
*   USF - U.S. FORCE INVENTORY
*   DNF6 - DESIRED NUCLEAR FRACTION FOR SOVIET UNION
*   RF - REST OF WORLD FORCE INVENTORY
*   RUOR - REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD
*   ROWFR - REST OF WORLD FORCE REQUESTS
*   FP - FORCE PRICE
*   RAVAL - REST OF WORLD FUNDS AVAILABLE
*
*
L RFRA.K(I1,I2)=RFRA.J(I1,I2)+DT*(RFRART.JK(I1,I2)-
X RFOR.JK(I1,I2)-RHOR.JK(I1,I2))
N RFRA(I1,I2)=RFRAI(I1,I2)
T RFRAI(*,1)=200/100/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T RFRAI(*,2)=300/150/50/40/40/20/20/30/0/0/20/30/50/0/
X 20/30/20/0
T RFRAI(*,3)=200/200/70/30/70/30/20/20/0/0/20/30/50/20/
X 20/40/20/0
*
*   RFRA - REST OF WORLD FORCE REQUEST APPROVED
*   RFRAI - REST OF WORLD FORCE REQUESTS APPROVED (INITIAL VAL
*   RFRART - REST OF WORLD FORCE REQUESTS APPROVAL RATE
*   RFOR - REST OF WORLD FOREIGN ORDERING RATE
*   RHOR - REST OF WORLD HOME ORDERING RATE
*
*
R RFOR.KL(I1,I2)=RFRA.K(I1,I2)-MIN(RFRA.K(I1,I2),RMIP.K(I1,I2))
*
R RHOR.KL(I1,I2)=MIN(RFRA.K(I1,I2),RMIP(I1,I2))
*
A RMIP.K(I1,I2)=ROWCAP.K(I1,I2)*FPDROW(I2)
*
C DNF6=.5
T FP=.1/.08/.034
```

```
*
*  RFOR - REST OF WORLD FOREIGN ORDERING RATE
*  RFRA - REST OF WORLD FORCE REQUESTS APPROVED
*  RMIP - REST OF WORLD MAXIMUM FORCE IN PRODUCTION
*  RHOR - REST OF WORLD HOME ORDERING RATE
*  ROWCAP - REST OF WORLD CAPITAL INVENTORY
*  FPDROW - FORCE PRODUCTION DELAY IN REST OF WORLD
*  DNF6 - DESIRED NUCLEAR FRACTION FOR SOVIET UNION
*  FP - FORCE PRICE
*
*
*
```

```
*
* ********************************************************
* *   SECTOR X - REST OF WORLD ARMS REQUESTS TO U.S.      *
* ********************************************************
*
*
*
*
L RFOT.K(I1,I2)=RFOT.J(I1,I2)+DT*(RFOR.JK(I1,I2)-
X RORTUS.JK(I1,I2)-RORR.JK(I1,I2))
N RFOT(I1,I2)=RFOTI(I1,I2)
T RFOTI(*,1)=300/120/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T RFOTI(*,2)=400/200/70/55/55/31/20/10/10/0/20/35/40/
X 10/20/28/10/0
T RFOTI(*,3)=250/180/50/30/50/40/30/35/10/8/30/40/60/
X 20/30/40/30/0
*
R RORTUS.KL(I1,I2)=(1-USHOST(I1))*RFOT.K(I1,I2)
*
R RORR.KL(I1,I2)=USHOST(I1)*RFOR.K(I1,I2)
*
*   RFOT - REST OF WORLD ORDERS (TOTAL)
*   RFOTI - REST OF WORLD ORDERS (INITIAL VALUES)
*   RFOR - REST OF WORLD FOREIGN ORDERING RATE
*   RORTUS - REST OF WORLD ORDERING RATE TO U.S.
*   RORR - REST OF WORLD ORDERING RATE TO REST OF WORLD
*   USHOST - PRECEIVED U.S. HOSTILITY TO REST OF WORLD
*
*
L RORUS.K(I1,I2)=RORUS.J(I1,I2)+DT*(RORTUS.JK(I1,I2)-
X ROPR.JK(I1,I2))
*
N RORUS(I1,I2)=RORUSI(I1,I2)
T RORUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T RORUSI(*,2)=0/50/30/20/10/20/16/5/0/0/0/20/20/0/
X 0/20/0/0
T RORUSI(*,3)=0/100/40/30/20/30/20/20/0/0/0/15/20/0/
X 0/30/0/0
*
*
R ROPR.KL(I1,I2)=DELAY3(RORTUS.JK(I1,I2),ROWOPD)
C ROWOPD=.5
*
T USHOST=1/0/0/0/.5/0/.2/0/1/.5/1/0/0/1/0/0/.5/0
*
*   RORUS - REST OF WORLD ORDERS RECEIVED BY U.S.
*   RORTUS - REST OF WORLD ORDERING RATE TO U.S.
*   ROPR - REST OF WORLD ORDERS TO U.S. PROCESSING RATE
*   RORUSI - REST OF WORLD ORDERS RECEIVED BY U.S. (INITIAL VA
*   ROWOPD - REST OF WORLD ORDERS TO U.S. PROCESSING DELAY
```

```
*   USHOST - PRECEIVED U.S. HOSTILITY TO REST OF WORLD
*
*
*
```

```
* **********************************************************
* *   SECTOR XI - REST OF WORLD UNFILLED ORDERS HELD BY     *
* *                THE U.S. AND THE REST OF THE WORLD       *
* **********************************************************
*
*
*
*
*
L ROPUS.K(I1,I2)=ROPUS.J(I1,I2)+DT*(ROPR.JK(I1,I2)-
X ROARUS.JK(I1,I2)-RODRUS.JK(I1,I2))
N ROPUS(I1,I2)=ROPUSI(I1,I2)
T ROPUSI(*,1)=0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T ROPUSI(*,2)=0/26/21/14/7/7/14/12/0/0/0/16/16/0/
X 0/16/0/0
T ROPUSI(*,3)=0/80/28/21/14/21/21/14/0/0/0/10/14/0/
X 0/21/0/0
*
*  ROPUS - PROCESSED REST OF WORLD ORDERS TO U.S.
*  ROPR - REST OF WORLD ORDERS TO U.S. PROCESSING RATE
*  ROARUS - REST OF WORLD ORDERS TO U.S. APPROVAL RATE
*  RODRUS - REST OF WORLD ORDERS TO U.S. DENIAL RATE
*  ROPUSI - PROCESSED REST OF WORLD ORDERS TO U.S. (INITIAL V
*
*
R ROARUS.KL(I1,I2)=ROPUS.K(I1,I2)*USI.K(I1,I2)
*
R RODRUS.KL(I1,I2)=ROPUS.K(I1,I2)*(1-USI.K(I1,I2))
A USI.K(I1,I2)=.7+STEP(.02,1983)
*
*  ROARUS - REST OF WORLD ORDERS TO U.S. APPROVAL RATE
*  ROPUS - PROCESSED REST OF WORLD ORDERS TO U.S.
*  USI - U.S. INCLINATION TO APPROVE ORDERS
*  RODRUS - REST OF WORLD ORDERS TO U.S. DENIAL RATE
*
*
L RUOUS.K(I1,I2)=RUOUS.J(I1,I2)+DT*(ROARUS.JK(I1,I2)-
X FDRR.JK(I1,I2))
N RUOUS(I1,I2)=RUOUSI(I1,I2)
T RUOUSI(*,1)=0/50/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T RUOUSI(*,2)=0/20/10/8/5/5/7/6/0/0/0/9/7/0/0/6/0/0
T RUOUSI(*,3)=0/40/20/12/10/14/15/8/0/0/0/7/0/0/0/10/0/0
*
*  RUOUS - REST OF WORLD UNFILLED ORDERS HELD BY U.S.
*  RUOUSI - REST OF WORLD UNFILLED ORDERS HELD BY U.S. (INITI
*  ROARUS - REST OF WORLD ORDERS TO U.S. APPROVAL RATE
*  FDRR - FORCE DEPLOYMENT RATE BY REST OF WORLD (U.S. PRODUC
*
*
L RUOR.K(I1,I2)=RUOR.J(I1,I2)+DT*(RHOR.JK(I1,I2)+
```

```
X RORR.JK(I1,I2)+RODRUS.JK(I1,I2)-FDRR.JK(I1,I2))
N RUOR(I1,I2)=RUORI(I1,I2)
T RUORI(*,1)=300/120/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
T RUORI(*,2)=400/200/70/55/55/31/20/10/10/0/20/35/40/
X 10/20/28/10/0
T RUORI(*,3)=250/180/90/38/50/40/30/25/10/8/30/40/50/
X 25/30/40/31/0
*
*   RUOR - REST OF WORLD ORDERS HELD BY REST OF WORLD
*   RUORI - REST OF WORLD ORDERS HELD BY REST OF WORLD (INITIA
*   RHOR - REST OF WORLD HOME ORDERING RATE
*   RORR - REST OF WORLD ORDERING RATE TO REST OF WORLD
*   RODRUS - REST OF WORLD ORDERS TO U.S. DENIAL RATE
*   FDRR - FORCE DEPLOYMENT RATE BY REST OF WORLD
*
*
*
```

```
*
* ****************************************************************
* *   SECTOR XII - REST OF WORLD FUNDS AVAILABLE                 *
* ****************************************************************
*
*
*
*
A RAVAL.K(1)=ROWGNP(1)*MFRAC(1)-SUMV(ROWCMF.K(1,*),1,3)-
X FP(1)*MIN(0,USF.K(1)*DNF6-RF.K(1,1)-RUOR.K(1,1))
A RAVAL.K(I4)=ROWGNP(I4)*MFRAC(I4)-SUMV(ROWCMF.K(I4,*),1,3)
*
T MFRAC=.0026/.0012/.0004/.0011/.0037/.0022/.0019/
X .0011/.0044/.0022/.0007/.0041/.0119/.0033/.0011/
X .0030/.0037/0
*
A ROWCMF.K(I1,I2)=CMF(I2)*(RF.K(I1,I2)+RUOUS.K(I1,I2)+
X RUOR.K(I1,I2))
*
T ROWGNP=9991/14000/4069/716/2437/170/129/121/46/50/
X 109/79/101/570/691/75/189/0
*
T CMF=.0004/.0181/.0041
*
*  RAVAL - REST OF WORLD FUNDS AVAILABLE
*  ROWGNP - REST OF WORLD GROSS NATIONAL PRODUCT
*  MFRAC - MILITARY FRACTION OF GROSS NATIONAL PRODUCT
*  ROWCMF - REST OF WORLD COST OF MAINTAINING FORCES
*  FP - FORCE PRICE
*  USF - U.S. FORCE INVENTORY
*  DNF6 - DESIRED NUCLEAR FRACTION FOR SOVIET UNION
*  RF - REST OF WORLD FORCE INVENTORY
*  RUOR - REST OF WORLD UNFILLED ORDERS HELD BY REST OF WORLD
*  RAVAL - REST OF WORLD FUNDS AVAILABLE
*  CMF - UNIT COST OF MAINTAINING FORCES
*
*
*
```

```
*
* ********************************************************
* *   SECTOR XIII - U.S. REAL GROSS NATIONAL PRODUCT      *
* ********************************************************
*
*
*
*
A USRGNP.K=GNPF.K+USPIR.K+SUM(TFPIR.JK)+.01
*
A GNPF.K=GNP62*EXP((TIME.K-1962)*LOGN(1+GNPGR))*
X (1+.15*SIN(6.28*(TIME-1962)/60)+.025*SIN(6.28*(TIME.K-
X 1962)/10)+.025*SIN(6.28*(TIME.K-1962)/3.33))+.01
*
C GNP62=8000
C GNPGR=.032
*
*  USRGNP - U.S. REAL GROSS NATIONAL PRODUCT
*  GNPF - GROSS NATIONAL PRODUCT FUNCTION
*  USPIR - U.S. PAYMENT TO DEFENSE INDUSTRY RATE
*  TFPIR - TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE
*  GNP62 - 1962 U.S. REAL GNP IN 1972 DOLLARS
*  TIME - CURRENT TIME OF MODEL
*  GNPRG - GROSS NATIONAL PRODUCT GROWTH RATE
*
*
A USLF.K=LFF.K+(USPIR.JK+SUM(TFPIR.JK))*EC
*
A LFF.K=DEP-(SMOOTH(GNPF.K,GNPFSC)-GNPF.K)/(32*GNPF.K)
*
C EC=.000049
C GNPFSC=5
*
S EUSBT.K=SUM(TFPIR.JK)-SUM(CMFO.K)
*
A CMFO1.K(I1,I2)=CMUSFO(I2)*USFO.K(I1,I2)
*
A CMFO.K(I1)=SUMV(CMFO1.K(I1,*),1,3)
*
T CMUSFO=.0004/.0181/.0041
*
*  USLF - U.S. LOBOR FORCE
*  LFF - U.S. LOBOR FORCE FUNCTION
*  USPIR - U.S. PAYMENT TO DEFENSE INDUSTRY RATE
*  TFPIR - TRUST FUND PAYMENT TO DEFENSE INDUSTRY RATE
*  EC - EMPLOYMENT CONSTANT
*  DEP - U.S. DESIRED EMPLOYMENT PERCENTAGE
*  GNPF - GROSS NATIONAL PRODUCT FUNCTION
*  GNPFSC - GROSS NATIONAL PRODUCT SMOOTHING CONSTANT
*  EUSBT - EFFECT ON U.S. BALANCE OF TRADE
```

```
*   CMFO - COST OF MAINTAINING U.S. FORCE OVERSEAS BY COUNTRY
*   CMFO1 - COST OF MAINTAINING U.S. FORCES OVERSEAS BY
*           SYSTEM AND COUNTRY
*   CMUSFO - COST OF MAINTAINING U.S. FORCES OVERSEAS (INPUT)
*   USFO - U.S. FORCES OVERSEAS
*
*
*
*
*
PLOT USFRRT(1)=1/USFRRT(2)=2/USFRRT(3)=3
PLOT USFR(1)=1/USFR(2)=2/USFR(3)=3
PLOT USFRPR(1)=1/USFRPR(2)=2/USFRPR(3)=3
PLOT USFRP(1)=1/USFRP(2)=2/USFRP(3)=3
PLOT USFRAR(1)=1/USFRP(1)=2/USPCFA=3
PLOT USFRAR(2)=1/USFRP(2)=2/USPCFA=3
PLOT USFRDR(1)=1/USFRP(1)=2/USPCFA=3
PLOT USFRDR(2)=1/USFRP(2)=2/USPCFA=3
PLOT USUO(1)=1/USUO(2)=2/USUO(3)=3
PLOT NUCT(1)=1/RF(1,1)=2/USHOST(1)=3
PLOT NUCT(2)=1/RF(2,1)=2/USHOST(2)=3
PLOT ROWLTF(1)=1,ROWLTF(2)=2/ROWLTF(3)=3
PLOT MAXLTF(1)=1/MAXLTF(2)=2/MAXLTF(3)=3
*
*
SPEC DT=.05/LENGTH=1990/PLTPER=.05
*
*
RUN
```

APPENDIX B

VARIABLE LIST

This appendix contains a complete list of all variables used in the Arms Transfer Model. The list contains the variable name, equation type, sector number of the equation, and a definition of each variable.

NAME	TYPE	SECTOR	DEFINITION
CFPUS	L	III	Completed force production by the United States.
CFPUSI	T	III	Table containing the initial values for US completed force production.
CFT	A	II	The total single country force requests (includes US and ROW requests).
CMF	T	VI	Table containing the unit cost of maintaining forces.
CMFO	A	XIII	The cost of maintaining US forces by individual country.
CMFO1	A	XIII	The cost of maintaining US forces overseas by system and country.
CMUSFO	A	XIII	The cost of maintaining US forces overseas.
CP	T	V	Table containing values for capital price.
CPR	A	VI	Rate at which industry pay for for capital investments.
CRF	A	II	An intermediate calculation used to compute US industry liquidity depletion rate.
CSF	A	V	Capital shortfall in industry.
CT	A	II	Perceived singlè country threat towards the US.
DAGR	C	II	Desired annual Gross National Product growth rate.
DC	C	VI	Disbursement constant for US defense industry liquidity.

NAME	TYPE	SECTOR	DEFINITION
DEP	C	II	Desired US employment rate.
DFGR	C	II	Desired US forces growth rate.
EC	C	XIII	US employment constant used in calculating US labor force.
EUSBT	S	XIII	The effort of arms transfers on US trade balance.
FC	C	VI	Force cost as a percentage of force price.
FDRR	R	III	Force deployment rate of US produced arms by the rest of the world.
FDRTS	R	III	Force deployment rate of US produced arms by the US.
FIPR	L	VII	Forces in production by the rest of the world.
FIPRI	T	VII	Table containing the initial levels the rest of the world forces in production.
FIPUS	L	III	Forces in production by the US.
FIPUSI	T	III	Table containing the initial levels of US forces in production.
FP	T	IX	Table containing the price of forces.
FPC	A	II	US force production capability.
FPDUS	T	III	Table of values which determine the force production delay for the US.
FPDROW	T	VII	Table of values which determine the force production delay for the rest of the world.
FPR	A	VI	Force payment rate to US industry from the US and the rest of the world.
FPRR	R	VII	Rest of the world force production rate.
FPRTUS	R	III	US force production rate.

NAME	TYPE	SECTOR	DEFINITION
GNPF	A	XIII	US Gross National Product product function.
GNPFSC	C	XIII	US Gross National Product product function smoothing constant.
GNPGR	C	XIII	US Gross National Product growth rate.
GNPSC	C	II	US Gross National Product smoothing constant.
ILP	A	II	US defense industry lobby pressure on Congress.
LFF	A	XIII	US labor force function.
LP	C	VI	Cost of US industry lobby pressure on Congress.
MAXLTF	A	I	Largest single country conventional threat against the US.
MAXNVC	A	I	Total tactical nuclear threat against the US.
MFRAC	T	XII	Table containing the military fraction of Gross National Product for all countries.
MUSCIP	C	V	Maximum proportion of US industry liquidity available for capital production.
NCI	C	Ø	Number of countries being considered in themodel.
NCNTRY	C	Ø	Number of countries in the model excluding the US.
NEIGH	T	Ø	Table that contains the necessary information to determine what neighbors a specific country has.
NF	A	IV	Indicates the size of a neighboring countries force.
NFN	A	IV	Neighbors threat to the rest of the world.

NAME	TYPE	SECTOR	DEFINITIONS
NUCT	A	I	Perceived single country tactical nuclear threat against the US.
OSFRAC	T	IV	US overseas force deployment fraction.
PFPRR	R	VII	Rest of worldplanned force production rate.
PFPRUS	R	III	US planned force production rate.
PTFRT	R	VI	Rate at which rest of the world makes payment to US trust fund.
PTFRTI	A	VI	Initial rate of payment to US trust fund by the rest of the world.
RAVAL	A	XII	Rest of the world funds available for production or procurement of arms.
RF	L	VII	Rest of the world force inventory.
RFI	T	VII	Table containing the initial levels of the rest of the world force inventory.
RFOR	R	IX	Rest of the world foreign ordering rate.
RFOT	L	X	Total rest of the world foreign orders.
RFOTI	T	X	Table containing the initial levels for rest of the world foreign orders.
RFRA	L	IX	Rest of the world force requests approved.
RFRAI	T	IX	Table containing the initial levels of force requests approved for the rest of the world.
RFRART	R	IX	Rest of the world force requests approval rate.
RFRI	A	VIII	Initial value for rest of the world forces requested.
RFRIR	A	VIII	Perceived rest of the world offensive forces required.

NAME	TYPE	SECTOR	DEFINITIONS
RFRR	R	VII	Force request rate by the rest of the world.
RHOR	R	IX	Rest of the world home ordering rate.
RHOST	T	IV	Perceived rest of the world hostility to the rest of the world.
RI	A	II	Regional instability factor.
RMIP	A	IX	Maximum force in production by the rest of the world.
ROARUS	R	XI	US approved rate for orders from the rest of the world.
RODRUS	R	XI	US denial rate for orders from the rest of the world.
ROPR	R	X	US processing rate for orders from the rest of the world.
ROPUS	L	XI	Processed orders from the rest of the world to the US.
ROPUSI	T	XI	Table containing the initial levels of processed order from the rest of the world to the US.
RORR	R	X	The rest of the world ordering rate to the rest of the world (exept home).
RORTUS	R	X	The rest of the world ordering rate to the US.
RORUS	R	X	The rest of the world unfilled orders held by the rest of the world.
RORUSI	T	X	Table containing the initial levels for the rest of the world unfilled orders held by the rest of the world.
ROWCAP	T	VII	Table containing the initial levels of capital inventory for the rest of the world.
ROWCMF	A	VI	The rest of the world cost of maintaining forces.

NAME	TYPE	SECTOR	DEFINITIONS
ROWFL	T	VII	Table containing the initial force levels of the rest of the world.
ROWFR	A	VIII	The rest of the world force requests.
ROWGNP	T	XII	Table containing the initial levels of Gross National Product for the rest of the world.
ROWIUS	T	IV	Table containing the perceived worth of the rest of the world to the US.
ROWLTF	A	I	The rest of the world single country conventional threat against the US.
ROWOPD	C	X	The rest of the world orders to the US processing delay.
ROWTF	A	VIII	The rest of the world total force by country.
RVOR	L	XI	The rest of the world unfilled orders held by the rest of the world.
RVORI	T	XI	Table containing the initial levels for the rest of the world unfilled orders held by the rest of the world.
RVOVS	L	XI	The rest of the world unfilled orders held by the US.
RVOVSI	T	XI	Table containing the initial levels for the rest of the world unfilled orders held by the US.
TCSF	A	V	The total capital shortfall
TF	L	VI	Per country trust fund amount.
TFI	T	VI	The initial trust fund levels for each country.
TFPIR	R	VI	The trust fund payment to defense industry rate.
TIME	C	Ø	Startup time of the simulation run.
UO	A	V	Total unfilled orders - worldwide

NAME	TYPE	SECTOR	DEFINITIONS
USART	R	VI	US defense appropriations rate
USCAP	L	V	US production capacity with respect to all countries (including the US)
USCAPI	T	V	Table containing the initial US production levels for all countries (including the US)
USCFEE	R	IV	The US CONUS forces retirement rate
USCIP	L	V	US capital in production
USCIPI	T	V	The initial level of US capital in production
USCL	T	V	Table containing US capital life expentancy values
USCPD	C	V	US capital production delay
USCPH	C	V	US capital production planning horizon
USCPR	R	V	US capital production rate
USCRRT	T	V	US capital retirement rate
USDIL	L	VI	The US defense industry liquidity
USDILI	C	VI	The initial level for defense industry liquidity
USF	A	IV	US force industry
USAF	L	VI	US force appropriations from Congress
USFAI	T	VI	Table containing the initial levels of US force appropriations
USFC	L	IV	Table containing the initial levels of US CONUS forces
USFL	T	IV	US CONUS forces retirement rate delay
USFO	L	IV	US forces overseas by country

NAME	TYPE	SECTOR	DEFINITIONS
USFODR	R	IV	US forces overseas deployment rate
USFODS	A	IV	US forces overseas deployment rate interim value
USFOI	T	IV	Initial values of US forces overseas by country
USFR	L	I	US force requests
USFRAR	R	I	Approval rate for US force requests
USFRDR	R	I	Denial rate for US force requests
USFRI	T	I	Initial levels of US force requests
USFRP	L	I	Processed US force requests
USFRPD	C	I	US force requests processing delay
USFRPI	T	I	Initial levels of US force requests processed
USFRPR	R	I	US force requests processing rate
USFSC	C	II	US forces smoothing constant
USFTD	A	IV	Maximum US forces deployable overseas
USHOST	T	X	Perceived US hostility towards the rest of the world
USI	A	XI	US inclination to approve the rest of the world orders
USILDR	R	VI	US defense industry liquidity depletion rate
USIROW	T	IV	US importance to the rest of the world
USLF	A	XIII	US labor force
USOFRR	R	IV	US overseas forces retirement rate
USPCFA	A	II	US pressure on Congress for force appropriations
USPCPR	R	V	US planned capital production rate

NAME	TYPE	SECTOR	DEFINITIONS
USPIR	R	VI	US payment to defense industry rate
USPSFA	A	II	Popular support for US defense appropriations
USRGNP	A	XIII	US real Gross National Product
USTF	A	VIII	Total US force level
USUO	L	I	US unfilled orders held by the US
USUOI	T	I	Initial levels of US unfilled orders
W1	C	II	Industrial lobby internal weighing factor
W2-W5	C	II	US pressure on Congress internal weighing factors

APPENDIX C

EXTERNAL FUNCTIONS

```
C
C
      REAL FUNCTION AMAX(WORD,N1,N2,RCNTRY)
      DIMENSION WORD(18)
C
      NCNTRY=RCNTRY
      X=WORD(1)
      DO 10 I=2,NCNTRY
      X=AMAX(X,WORD(I))
   10 CONTINUE
      AMAX=X
      RETURN
      END
C
C
      REAL FUNCTION AMAXX(WORDS,N1,N2,RCNTRY,I1)
      DIMENSION WORDS(18,4)
C
      NCNTRY=RCNTRY
      X=WORDS(I1,1)
      DO 10 J=2,4
      X=AMAX1(X,WORDS(I1,J))
   10 CONTINUE
      AMAXX=X
      RETURN
      END
C
C
      REAL FUNCTION AMAXXX(WORDS(N1,N2,RCNTRY,I1)
      DIMENSION WORDS(18,1,4)
C
      X=WORDS(I1,1,1)
      DO 10 J=2,4
      X=AMAX1(X,WORDS(I1,1,J))
   10 CONTINUE
      AMAXXX=X
      RETURN
      END
C
C
      REAL FUNCTION FIND1(ARAY1,N1,N2,ARAY2,N3,N4,J1,J2,J3,RCI)
      DIMENSION ARAY1(19,4),ARAY2(19,4)
C
      FIND1=ARAY1(ARAY2(J1,J3),J2)
      RETURN
      END
C
C
      REAL FUNCTION FIND2(ARAY1,N1,N2,ARAY2,N3,N4,J1,J3,RCI)
      DIMENSION ARAY1(19),ARAY2(19,4)
```

```
C
      FIND2=ARAY1(ARAY2(J1,J3))
      RETURN
      END
C
C
      REAL FUNCTION FIND3(ARAY1,N1,N2,ARAY2,N3,N4,ARAY3,N5,N6,J1,J3,R)
      DIMENSION ARAY1(19,4),ARAY2(19,4),ARAY3(19)
C
      DO 10 I=1,4
      IF(J1.EQ.ARAY2(ARAY2(J1,J3),I))GO TO 20
   10 CONTINUE
   20 FIND3=ARAY1(ARAY2(J1,J3),I)*ARAY3(ARAY2(J1,J3))
      RETURN
      END
C
```

VITA

Captain Mark E. Nickell

Mark Edward Nickell was born on September 16, 1953, in Minneapolis, Minnesota. He graduated from high school in Burnsville, Minnesota in 1972 and attended the University of Minnesota, from which he received a degree of Bachelor of Liberal Arts in June, 1976. Upon graduation he began his Air Force career at the Foreign Technology Division, Wright-Patterson Air Force Base until entering the School of Engineering, Air Force Institute of Technology, in September 1980.

Permanent address: 12504 Chippewa Lane
Burnsville, MN. 55337

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFIT/GST/OS/82M-10	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): A SYSTEM DYNAMICS APPROACH TO MODELING THE US ARMS TRANSFER PROCESS	5. TYPE OF REPORT & PERIOD COVERED: MS THESIS
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Mark E. Nickell	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Air Force Institute of Technology (AFIT/EN) Wright-Patterson AFB, Ohio 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: March 1982
	13. NUMBER OF PAGES: 204
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

Lynn Wolaver
LYNN E. WOLAVER
Dean for Research and Professional Development
AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)
WRIGHT-PATTERSON AFB, OH 45433

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

4 JUN 1982

APPROVED FOR PUBLIC RELEASE; IAW AFR 190-17

~~FREDRIC C. LYNCH, [illegible], USAF~~

~~Director of Public Affairs~~

18. SUPPLEMENTARY NOTES

ARMS TRANSFERS
FOREIGN MILITARY SALES
SIMULATION
WORLD STABILITY
ARMS SALES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The transfer of arms between countries plays a significant role in the political, economic, and military affairs of the entire world, and is, consequently, subject to constant criticism and review from many quarters. Because of the complexity of the relationships in, and the diversity of opinion about arms transfers, a concise policy which will satisfy everyone is virtually impossible to devise. This thesis is an attempt

to bring together all of the significant variables concerning the arms transfer system, with particular emphasis on the welfare of United States' national interests. While this model will not be able to produce policies which will keep all interested parties satisfied, it should depict the consequences of arms transfer decisions in terms of the major variables. The model will also facilitate the examination of policies such as the dollar ceiling on sales in terms of impact on the strategic position and economy of the United States.